

REPORT
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Strategic Energy Research

SECONDARY DISTRIBUTION IMPACTS OF RESIDENTIAL ELECTRIC VEHICLE CHARGING

Gray Davis, Governor

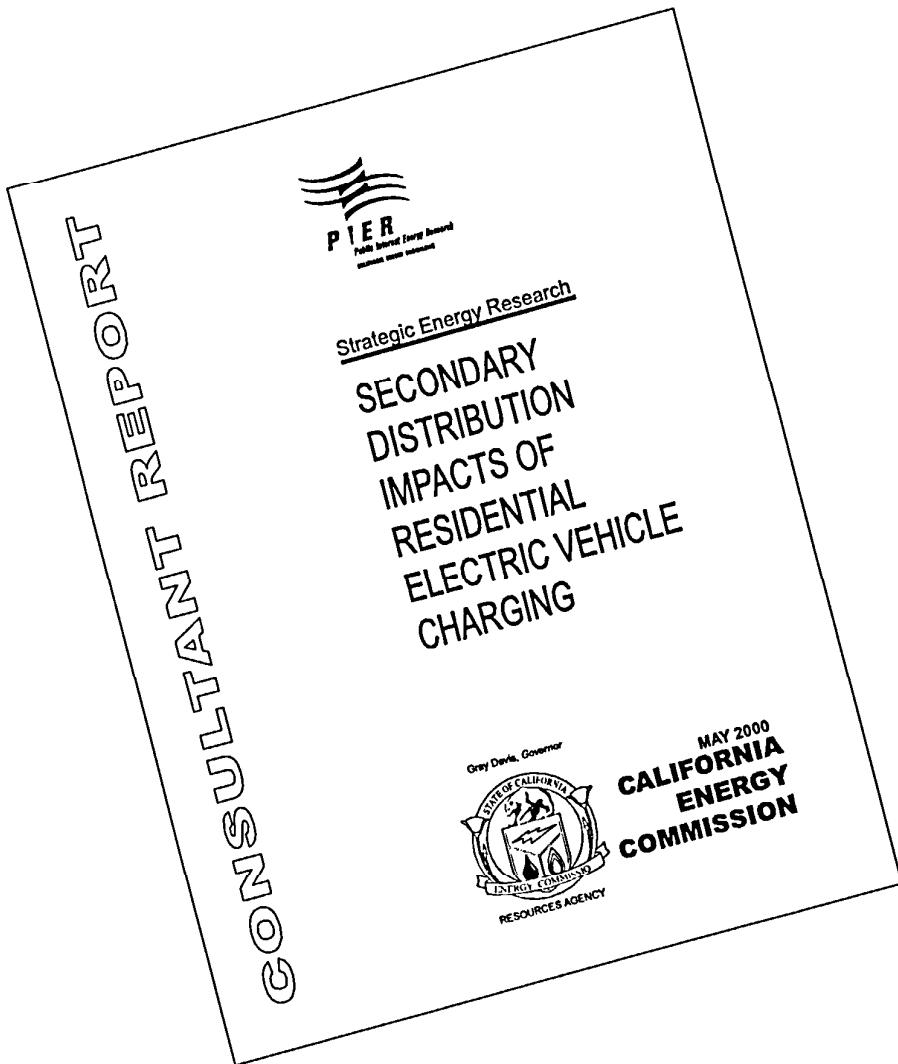
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Prepared for:

CALIFORNIA ENERGY
COMMISSION

Laurie ten Hope, Program Lead

STRATEGIC ENERGY RESEARCH

Prepared by:

Frank Lambert, *Program Manager*

GEORGIA TECH

Mark Rawson, Project Manager

ENERGY TECHNOLOGY DEVELOPMENT
DIVISION

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Final Report

Secondary Distribution Impacts of Residential Electric Vehicle Charging

May 11, 2000



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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to \$62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

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- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research.

What follows is the final report for the NEETRAC Project No. 99-373 conducted by the Georgia Institute of Technology. The report is entitled secondary Distribution Impacts of Residential Electric Vehicle Charging. This project contributes to the Strategic Energy Research program.

For more information on the PIER Program, please visit the Commission's Web site at:
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Secondary Distribution Impacts of Residential Electric Vehicle Charging

Executive Summary

The market penetration of large single-phase residential loads, such as the Electric Vehicle (EV) charger, is a potential power quality, power delivery and energy consumption concern for electric power providers and consumers in terms of distribution reliability, house or site electrical system reliability and vehicle life cycle costs. Charging systems with high harmonic current distortion can result in secondary distribution line de-rating or losses resulting in economic and quality of service consequences. These losses also have an economic penalty to consumers because they ultimately increase the cost of electricity to the end user. The objective of this project was to examine the secondary distribution impacts of EV charging.

This research was sponsored by the California Energy Commission, California Electric Transportation Coalition, Florida Power and Light, Georgia Power Company, Pacific Gas and Electric Company, Sacramento Municipal Utility District, Southern California Edison, and Virginia Power Company.

The project team was composed of the following technical advisors: California Energy Commission – Mark Rawson, California Electric Transportation Coalition – Cecile Martin, Florida Power and Light – Bob Suggs, Georgia Power Company – John Kennedy, Pacific Gas and Electric Company – Christina Jennings and Gil Hensley, Sacramento Municipal Utility District – Steve Revenaugh, Southern California Edison – Brian Sisco and Ernie Morales, and Virginia Power Company – Dan Ward. These advisors were experienced in both power quality and electric vehicle charging systems and were responsible for providing technical oversight and direction for the project.

The National Electric Vehicle Infrastructure Working Council (IWC); composed of utilities, automobile companies, and equipment manufacturers; was initiated to develop consistent standards for the EV infrastructure to meet the needs of the marketplace. John Kennedy served as Chairman of the Distribution, Load Management, and Power Quality Committee of the IWC. This committee developed a Record of Consensus on the power factor and current distortion requirements for light duty on-road EV chargers and identified the need for this project to validate their recommendations.

The project was divided into four phases:

- Phase 1: Data Collection
- Phase 2: Model Development and Validation
- Phase 3: Simulation Case Studies
- Phase 4: Field Site Testing and Validation

Phase 1 of the project was designed to collect data from residential electrical appliances and EV chargers. A “case study” approach based on two homes was selected to collect data for the simulation studies. Profiles were captured for nominal and undervoltage conditions from over

seventy appliances and seven EV chargers. Distribution system configurations likely to see EV loads were obtained from the utilities along with distribution transformer and service data.

In the second phase, all appliances and EV chargers were modeled as non-linear loads, based on the measurements taken in the first phase of the project. The models developed for this study were implemented and simulated in Electrotek's HarmFlo+ workstation package. The model development process was automated by a Translator program written in PASCAL, which takes in the appliance data and generates the HarmFlo+ code. The models were validated by comparing the simulations to actual measurements for particular case scenarios performed at one of the homes used in the initial characterization of the appliances. The measurements taken and simulations performed during this stage validated the models implemented in Electrotek's HarmFlo+ software for the appliances and electric vehicle chargers.

During the third phase, simulation case studies representative of the electrical service configurations of the participating utilities were performed. Utility system data were provided to a Compiler program written in PASCAL to translate the input data into HarmFlo+ input files. The studies considered various mixes of appliances and chargers and provided a significant evaluation of worst-case conditions. Further, evaluations of the utility distribution transformer and secondary distribution conductors for both de-rating and line losses due to the increase in harmonic currents were also performed. The worst-case simulation scenario resulted in a voltage total harmonic distortion (THD) of 5.1% on the secondary side of the distribution transformer, which is just over the Institute of Electrical and Electronic Engineers (IEEE) 519 Recommended Practice which recommends a 5% limit for voltage distortion. This value was obtained with a computer simulation of a charger designed to the absolute limits of current distortion at each harmonic frequency (IEC 1000-3-4) and is not representative of current commercial light-duty on-road EV chargers. The 5% level of IEEE 519 is a recommended limit that has turned out to be generally a conservative number. In normal practice, levels up to 8% may not cause a problem. Specific harmonic frequencies may cause problems below that level as opposed to the aggregated value of THD.

Field Tests were performed by three participating utilities during the fourth phase of this project. The field test sites were comprised of two residential sites and a commercial site. Measurements were taken at the three field test sites for a month. The absolute worst-case recorded voltage THD was 4.1%, which is below the IEEE 519 recommended 5% limit for voltage distortion. Simulation of one of the test sites was performed to compare the actual field data with the simulation model results. The field data and the simulation results for the voltage THD matched within 2.9%, thus validating the simulation process. Temperature variation on the transformer due to EV charging was also studied in one field site.

The main conclusions of the project based upon the utility systems and chargers investigated are:

- Commercial light-duty on-road EV chargers engineered to National Electric Vehicle Infrastructure Working Council (IWC) guidelines based upon IEC 1000-3-4 do not give rise to excessive voltage THD on the secondary side of the transformer. Two critical elements that make these guidelines effective are a minimum total power factor of 95% and a maximum current THD of $\leq 20\%$.

- The rise in voltage THD due to EV charging was found to be within 0.8% in all three field test sites and should not be a cause for concern. Load management strategies like off peak charging should be encouraged to minimize the load impacts on the distribution system.
- The influence of EV charging on transformer temperature at one field site was studied. Temperature rise was not attributable to voltage THD but was affected rather by the extra loading on the transformer from the EVs.
- The main cause of concern is the overloading of the distribution transformer with widespread use of EV chargers, assuming the chargers meet voluntary IWC guidelines such that voltage THD is not an issue. Still, utility service planning groups should ask for kVA and true power factor values in addition to kW values for any rectifier or other non-linear load.

Interim results of this project have been presented and published at the North American Electric Vehicle Infrastructure Conference in November of 1999. A final report will be presented at the Electric Vehicle Symposium in October of 2000. Project results have also been provided to the IEEE Task Force on Single Phase Harmonics and a summary will be provided to EPRI for release to the IWC.



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First Interim Report

Secondary Distribution Impacts of Residential EV Charging



FIRST INTERIM REPORT

April 1999

Project Title: Secondary Distribution Impacts of Residential EV Charging

Investigators: Dick Bass, NEETRAC, ECE Associate Professor (Co-Principal Investigator)
Frank Lambert, NEETRAC, Program Manager (Co-Principal Investigator)
Russ Davis, NEETRAC, ECE Graduate Research Assistant
Vinod Rajasekaran, NEETRAC, ECE Graduate Research Assistant
John Kennedy, Georgia Power Company (Project Advisor)

Abstract: This first of three interim reports documents electrical appliance and charger profiles captured during the data collection phase of this project. The report also documents typical distribution transformer and circuit data from participating utilities.

Secondary Distribution Impacts of Residential EV Charging

First Interim Report

Abstract

This first of three interim reports documents electrical appliance and charger profiles captured during the data collection phase of this project. The report also documents typical distribution transformer and circuit data from participating utilities.

Background

The market penetration of large single-phase residential loads, such as the 6.6 kW electric vehicle (EV) battery charger, is a potential power quality, power delivery, and energy consumption concern for electric power providers and consumers in terms of distribution system reliability, house or site electrical system reliability, and vehicle life cycle costs. Charging systems with high harmonic current distortion can result in secondary distribution line de-rating or losses resulting in economic and quality of service consequences. These losses also have an economic penalty to consumers because they ultimately increase the cost of electricity to the end user. The objective of this project is to examine the secondary (customer-side) distribution impacts of residential EV charging. The project is divided into four phases:

Phase 1: Data Collection (Winter 1999)

Phase 2: Model Development and Validation (Spring 1999)

Phase 3: Simulation Case Studies (Summer and Fall 1999)

Phase 4: Site Testing and Validation (Summer and Fall 1999, Winter 2000)

Methodology

A two-step selection process was used in choosing the appliances for this study. First, two homes were randomly chosen. The first home was built in the early 1970's and the second home was built in the early 1990's. Every appliance (whose power consumption exceeded five watts) in these two homes was tested for inclusion in the appliance library for possible use in Phase 3 of this project. This list of appliances was then reviewed by the utility sponsors, and additional appliances were added based on that input.

The sampling of appliances was intentionally not biased towards a "worst case" or a "most likely" scenario. Instead, this project is taking a "case study" approach based on two randomly sampled homes for simulation study and a number of field test sites for experimental study. In the simulation studies, various scenarios will be considered – including a "worst case" mix of appliances and a "typical" mix of appliances.

A statistically significant sample of appliances, corresponding to the national distribution of use patterns is well beyond the scope of this study. The approach taken in this study is more appropriately thought of as contributing convincing "circumstantial evidence" to the existing body

of experience and practice. The simulation case studies, together with the field tests in Phase 4 of this project is expected to provide ample “circumstantial evidence” to the utility participants to allow them to forecast the likely secondary distribution impacts of residential EV charging.

Electrical Appliance Summary

A total of 40 appliances were tested at both rated (100%) and reduced (90%) voltage. The summary tables below provide an overview of electrical characteristics organized by appliance category. It was noted that high current distortion (low power factor) appliances were primarily home entertainment and home office appliances. Complete data for each appliance is included in the Appendices A.2 -A.7.

Kitchen Appliances

Appliance	Power (W)	Power Factor	THD (Current) %	DPF
Mixer (High Power)	109.29	0.99	6.69	0.99
Mixer (Low Power)	58.29	0.60	77.33	0.76
Coffee Maker	960	1.0	1.77	1.0
Microwave	1340	0.97	21.82	1.0
Toaster	790	1.0	1.18	1.0

Home Entertainment

Appliance	Power (W)	Power Factor	THD (Current) %	DPF
Television Set	70	0.57	135.23	0.96
VCR	27.10	0.85	50.56	0.95
Cassette Player	19	0.53	138.80	0.90
CD Player	13.09	0.78	77.54	1.00
Stereo	110	0.76	78.79	0.97
Satellite Dish	19	0.53	138.80	0.90

Home Office

Appliance	Power (W)	Power Factor	THD (Current) %	DPF
Hard Disk Drive	60.0	0.59	131.91	0.99
Monitor	71.07	0.61	108.68	0.90
Scanner	17.06	0.62	117.93	0.99
Printer	16.06	0.74	54.54	0.86
Photo Copier (at start)	920	1.0	6.83	1.0
Photo Copier (at end)	90	0.79	75.70	0.99
FAX Machine	22	0.62	94.27	0.86
Answering Machine	9	0.71	82.99	0.96
UPS	60.06	0.80	68.85	0.98

Other Household Appliances

Appliance	Power (W)	Power Factor	THD (Current) %	DPF
Light Bulb	60.01	0.99	7.38	0.99
Compact Fluorescent Bulb	13	0.63	101.80	0.93
Compact Fluorescent Light	25	0.59	125.35	0.98
Light Dimmer	50.52	0.73	68.30	0.88
Electronic ballast	21.52	0.63	15.18	0.62
Vacuum Cleaner	1250	0.98	13.29	0.99
Portable Heater	1370	1.00	2.51	1.00
House Fan (High Speed)	620	0.80	2.49	0.80
House Fan (Low Speed)	300	0.50	31.63	0.51
Hair Dryer (High Power)	1070	1.00	1.65	1.00
Hair Dryer (Low Power)	520	0.91	44.20	1.0
Garbage Disposal Unit	117.79	0.87	46.26	0.95
Drill	220	0.96	21.63	0.98
Garage Door Opener	510	0.95	18.88	0.98

Heating and related Equipment

Appliance	Power (kW)	Power Factor	THD (Current) %	DPF
Heat Pump (Low Power)	0.51	0.93	4.27	0.93
Heat Pump (Medium Power)	2.32	0.78	8.60	0.78
Heat Pump (High Power)	4.81	0.95	7.13	0.95
Water Pump	1.18	0.78	7.02	0.78
Water Heater	4.33	1.0	2.05	1.0
Air Conditioner	1.68	0.97	9.41	0.98

Other High Power Appliances

Appliance	Power (kW)	Power Factor	THD (Current) %	DPF
Washing Machine	0.42	0.54	5.24	0.53
Washing Machine (Spin Cycle)	0.42	0.56	5.54	0.56
Drier	4.81	1.0	2.04	1.0
Refrigerator	0.61	1.0	1.96	1.0
Oven	5.81	1.0	1.78	1.0
Range	10.02	1.0	1.46	1.0
Dish Washer	1.27	0.97	2.95	1.0

Charger Data Summary

Four chargers were characterized at rated (100%) and reduced (90%) voltage at the beginning and end of charging. The tables below provide a summary of the charger characteristics. Complete data for each charger is included in Appendix A.8. The harmonic data of the chargers is also presented in the Appendix A.9.

Charger Characteristics at beginning of charging

Vehicle	Charger and Connecting Station	Power (KW)	Power Factor	THD (Current) %	DPF
GM EV1	WM200 on SCI	7.05	1.0	3.00	1.0
GM S10	WM200 on SCI	7.11	1.0	2.98	1.0
Toyota RAV4	SCI	4.83	1.0	2.53	1.0
	EVI#00617	4.74	1.0	2.36	1.0
Ford Ranger	SCI	5.61	1.0	5.26	1.0

Charger Characteristics at end of charging

Vehicle	Charger and Connecting Station	Power (KW)	Power Factor	THD (Current) %	DPF
GM EV1	WM200 on SCI	1.07	0.96	28.11	0.99
GM S10	WM200 on SCI	1.13	0.96	27.57	0.99
Ford Ranger	SCI	0.78	0.99	8.59	0.99

A comparison was undertaken to examine how different types of conductive connecting stations influenced the charger load characteristics. A Toyota Rav-4 was tested on two different connecting stations. Allowing for differences in test conditions, the effect of connecting station on the charger characteristics was negligible as is evident from the table below. More detailed test results are provided with the charger characteristics in AppendixA.8

Comparison of charger characteristics for different connecting stations

Connecting Station	Power (KW)	Power Factor	THD
SCI	4.83	1.0	2.53
EVI	4.74	1.0	2.36

Load Model Summary

The summary tables in this section provide an overview of electrical characteristics organized by electrical load model type: constant impedance (linear) or constant power. This was determined by comparing the electrical characteristics at rated voltage (100%) and reduced voltage (90%). When an appliance exhibited less than 5% change in impedance or power, the loads were classified into one of these two categories. Some appliances had several operating modes, and it was noted that constant power or constant impedance behavior depended on the operating mode. Four such appliances are given in the “dual mode” table.

The analysis presented in this section will be utilized during the next phase of this project to more accurately model the electrical appliances for computer simulation. Complete data for each appliance is included in Appendices A.2-A.7.

Constant Impedance Loads (High Power)

Appliance	Power (kW)	Power Factor	Impedance at rated voltage (ohms)	Impedance at reduced voltage (ohms)	% change in Impedance
Drier	4.81	1.0	11.67	11.65	0.17
Water Heater	4.33	1.0	13.35	13.22	0.97
Refrigerator	0.61	1.0	24.08	24.55	1.7
Oven	5.81	1.0	9.50	9.19	3.26
Range	10.02	1.0	5.41	5.15	4.8
Toaster	0.79	1.0	17.33	17.27	0.35
Garage Door	0.51	0.95	26.22	26.64	1.6
Vacuum Cleaner	1.25	0.98	11.41	11.43	0.18

Constant Power Loads

Appliance	Power Factor	Power at rated voltage(W)	Power at reduced voltage(W)	% change in Power
VCR 1	0.49	16.09	16.09	0.0
Satellite Dish	0.53	19.00	20.0	5.3
Computer 2	0.66	120.00	120.0	0.0
FAX Machine	0.62	22.00	22.00	0.0
Battery Recharger	0.49	35.09	35.09	0.0
Scanner	0.61	17.06	17.06	0.0
Computer Monitor	0.61	71.07	71.07	0.0

Dual Mode Devices

Appliance	Power (W)	Power Factor	THD (Current) %	% change in impedance for 10 % reduction in voltage	% change in current for 10% reduction in voltage
Coffee Maker (heating)	960.00	1.00	1.77	1.47	12.98
Coffee Maker (resting)	13.76	.76	35.24	10.14	0.0
Mixer (high)	109.29	.99	6.68	4.65	5.40
Mixer (low)	58.29	.60	61.17	7.44	2.40
Fan (High Speed)	620	.80	2.50	9.98	0.59
Fan (Low Speed)	300	.50	31.63	4.92	17.0
Hair Dryer (High Power)	1070	1.0	1.65	0.39	9.95
Hair Dryer (Low Power)	520	0.91	44.20	0.50	9.38

Harmonic Diversity Summary for Appliances

The phasor diagrams shown in Fig. 1 present the harmonic data in a phasor diagram format (harmonic current amplitude and phase angle for each individual appliance appears as a single line). The circle border represents an amplitude of 0.6 Amps. This format is intended to provide a means of identifying trends and not specific appliances. It can be seen that for the higher harmonic frequencies, the current amplitudes are very small for the appliances tested.

Differences in phase angle will result in harmonic phase cancellation by the currents injected by the various appliances. This effect is illustrated in Fig. 2, where the phasor sum of all appliances show the net current that would be expected at the service panel entrance if all appliances were on simultaneously. For these plots, the circle border represents an amplitude of 5 Amps.

The harmonic phasor sum diagrams in Fig. 2 clearly illustrate that the 3rd and 5th harmonic currents are expected to be the most significant. The 3rd and 5th harmonics are examined in more detail in Fig. 3 on 0.6 Amp circles. In this figure, the appliances are categorized as low power if they consume less than 150 W, and high power if greater than 150 W. The diagrams of Fig. 3 illustrate that harmonic currents resulting from low power appliances are expected to be relatively significant when compared to high power appliances. When considering the impact of harmonic currents, it is the magnitude of harmonic current in amps that is of importance. The current THD can be very misleading when considering lower power levels, since the current THD figure is a percentage of the fundamental. For example, there is not a significant difference in the EV charger harmonic current magnitude at the beginning (high power) and end (low power) of the charge cycle. The current THD is higher, not because the harmonic levels are higher but because the fundamental component is lower. Consequently, for the specific EV chargers tested the changes in harmonic characteristics over a charge cycle will not be a critical variable. This is illustrated Fig. 4 and Appendix A.9.

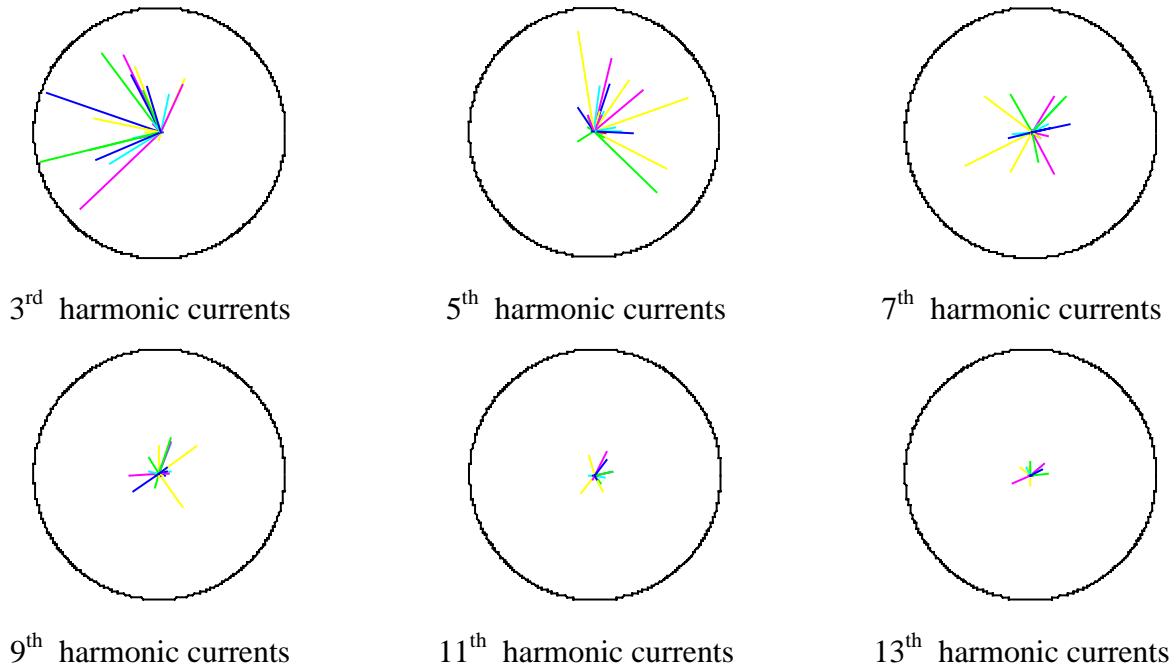


Figure 1: Phasor diagram of harmonic currents for all appliances on 0.6 A circles

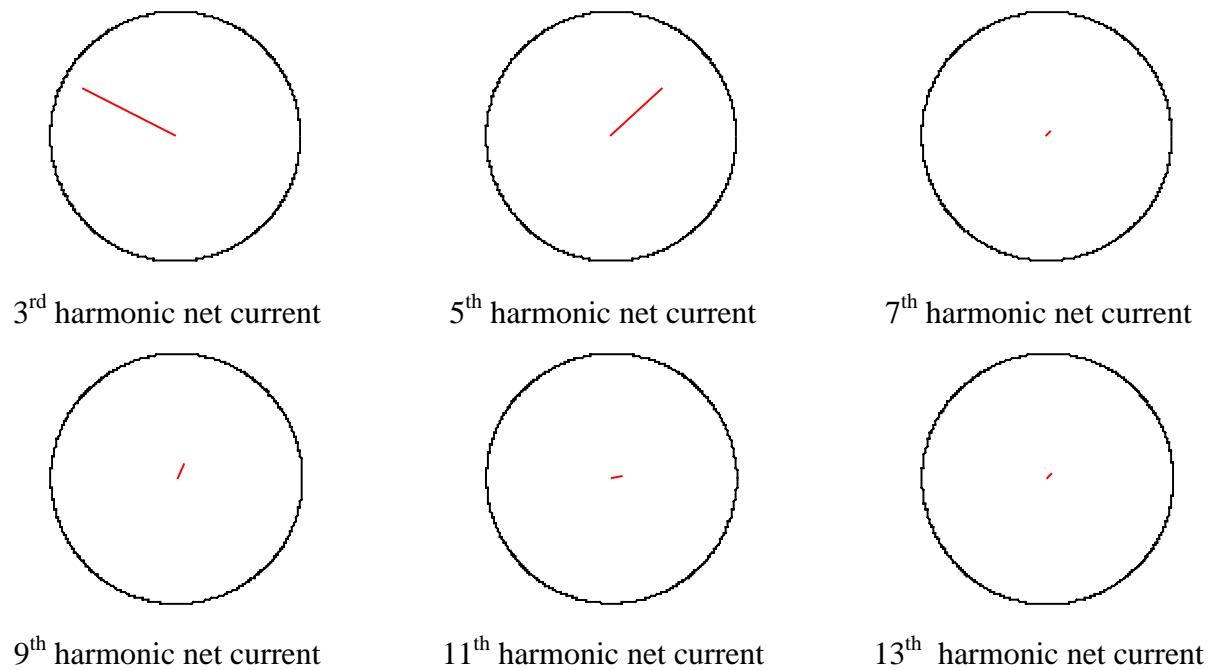


Figure 2: Phasor sum of harmonic currents for all appliances on 5.0 A circles

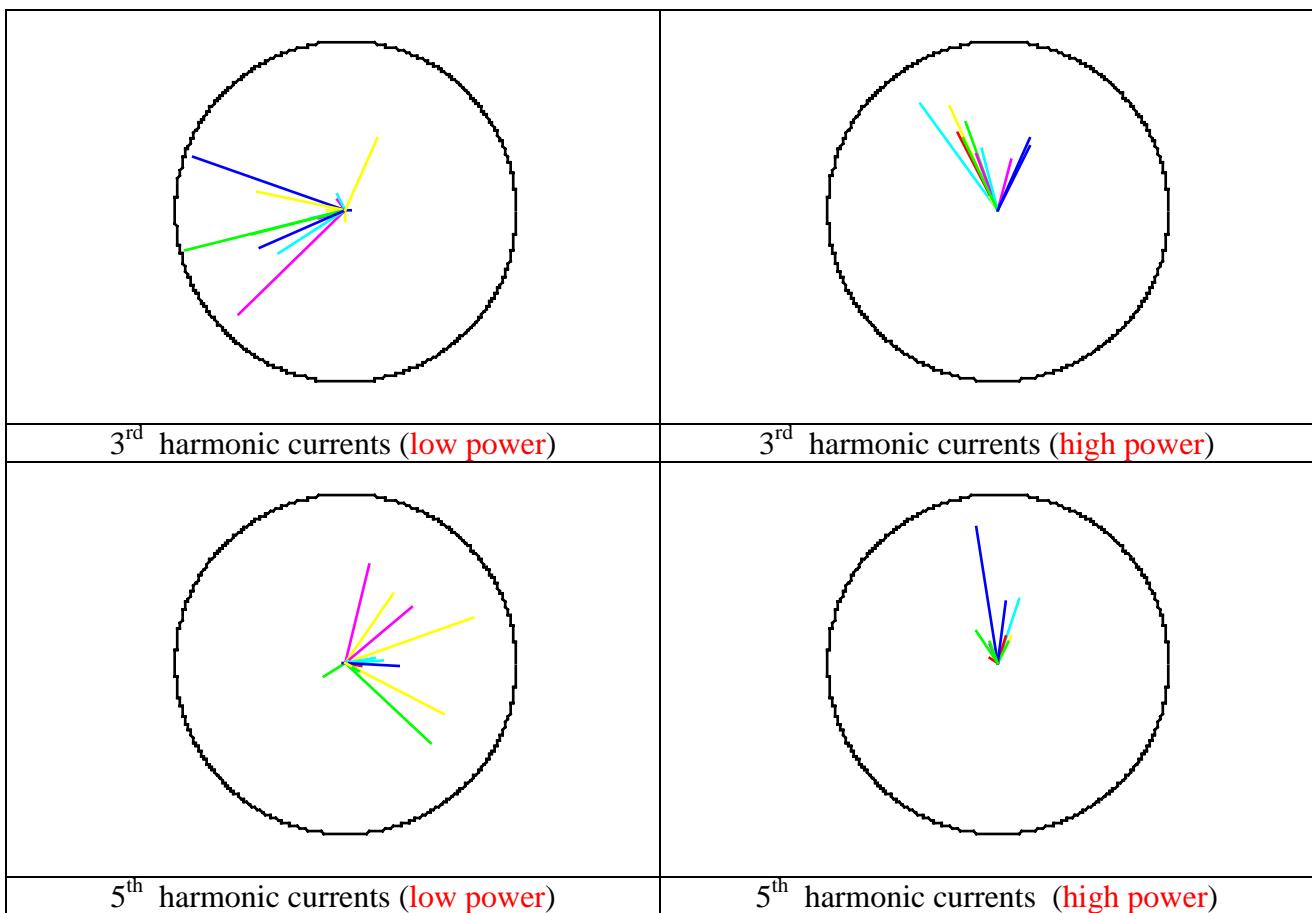


Figure 3: Phasor diagram of 3rd and 5th harmonic currents for low power (< 150 W) and high power (> 150 W) appliances on 0.6 A circles

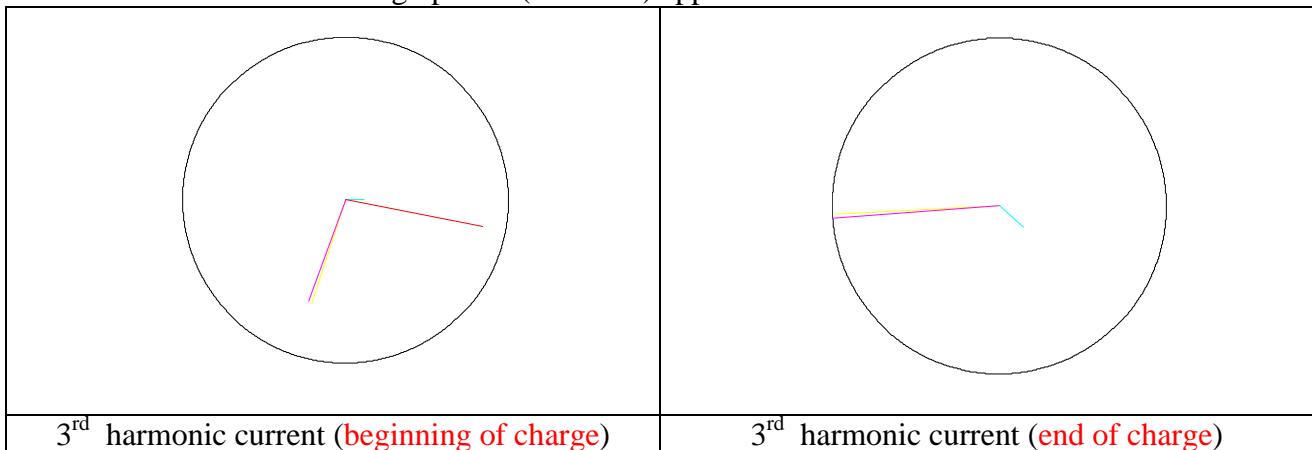


Figure 4: Phasor diagram of 3rd harmonic currents for 4 EV Chargers at beginning and end of charge cycle on 1.25 A circles

Instrument Comparison

A Fluke 41B harmonics meter was used to capture the voltage and current waveforms at 100% and 90% rated voltage. For comparison purposes, a BMI 3030A was also used to characterize several appliances. A summary of these comparisons appears in Appendix A.1. The BMI measurements deviate less than 10% from the Fluke measurements. THD (current) is the exception, where discrepancies of as much as 27% were noted.

The data presented in this section is not intended to be complete or conclusive. It is simply intended to present an example that illustrates the variance in instrument accuracy. If measurement repeatability were an issue, this would certainly be a concern. However, for this simulation study high precision measurements are not required because of the variability introduced by the random selection of appliances and the mix of appliance operation considered in Phase 3.

Utility System Data

The utilities represented in this report are identified in an identity-protected format. Each utility was asked to provide typical distribution transformer and secondary line data in their service territory. The tables below summarize the key data provided by the utilities. Complete transformer and line data provided by the utilities is included as Appendix A.10.

Overhead Line Data

	Util. "A"	Util. "B"	Util. "C"	Util. "D"	Util. "E"	Util. "F"
Rated KVA	37.5	25	25/50	37.5	50	*
Impedance (%)	1.75	2.06	1.2-1.4	1.4	2.17	*
Customers Served	15	13	*	4	4	*
Service Length (ft.)	100	80	*	75	200	*

Underground Line

	Util. "A"	Util. "B"	Util. "C"	Util. "D"	Util. "E"	Util. "F"
Rated KVA	50	25	25/50	50/75	50	*
Impedance (%)	1.75	1.87	1.2-1.4	1.8	2.17	*
Customers Served	20	6-8	*	5-7	8	*
Service Length (ft.)	125-130	110	*	200	200	*

* information not provided.



Second Interim Report

Secondary Distribution Impacts of Residential EV Charging



SECOND INTERIM REPORT

June 1999

Project Title: Secondary Distribution Impacts of Residential EV Charging

Investigators: Dr. Ron Harley, NEETRAC, ECE Professor (Co-Principal Investigator)
Frank Lambert, NEETRAC, Program Manager (Co-Principal Investigator)
Russ Davis, NEETRAC, ECE Graduate Research Assistant
Vinod Rajasekaran, NEETRAC, ECE Graduate Research Assistant
Jason Pierce, NEETRAC, ECE, Student Assistant
John Kennedy, Georgia Power Company (Project Advisor)

Abstract: This second of three interim reports documents the modeling protocol of electrical appliance and EV charger profiles captured during the data collection phase of this project. The report also describes how the measurements taken and simulations performed during this stage conclusively validate the models implemented in Electrotek's HarmFlo+ software for the appliances and electric vehicle chargers. This report documents the successful completion of Phase 2 of the planned project outline.

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Second Interim Report

Abstract

This second of three interim reports documents the modeling protocol of electrical appliance and EV charger profiles captured during the data collection phase of this project. The report also describes how the measurements taken and simulations performed during this stage conclusively validate the models implemented in Electrotek's HarmFlo+ software for the appliances and electric vehicle chargers. This report documents the successful completion of Phase 2 of the planned project outline.

Translators

The process of translating appliance and EV charger data in the form of harmonic summaries into HarmFlo code can be a time-consuming and a tedious process. Since the information is already in electronic form, it is possible to automate the process of generating the HarmFlo libraries of the models. Appliance data in the form of Fluke41 files were provided to a Conversion Program written in PASCAL to translate these files to HarmFlo model code.

Modeling Protocol

All appliances and electric vehicle chargers were modeled as non-linear loads based on the measurements taken in the first phase of this project. The models developed for this study were implemented in Electrotek's HarmFlo+ workstation simulation package. In addition, the option of linear load modeling was incorporated into the Conversion Program to reduce the complexity of the simulation process. As an example, the models of the oven and the Ford Ranger EV charger with EVSE (EV Supply Equipment) are shown in Appendix B.1. The models were incorporated into library files, which were classified in a similar fashion to that done in the first phase of the project.

Model Validation

The models were validated by comparing the simulations to actual measurements for particular case scenarios performed at a test home. One of the homes used in the initial characterization of the appliances was used as the model validation home. This home is the only load connected to a 25 kVA pad-mounted UD transformer with a 14.4 kV primary side line voltage. The configuration of the tested feeder is provided in Fig. 1. The typical parameters of the conductors and the transformer are shown in Tables A and B. Data were collected on the secondary of the distribution transformer with the Fluke41B Power Harmonics Analyzer for various case scenarios. Since HarmFlo does not provide a transformer model with a split secondary winding for +120V, 0V, -120V, the measurements were done with the 120V loads connected to the same 120V feeder. A sample measurement of the voltage at the low side of the transformer was taken and then reflected back to the high side to be used in the simulations to take into account the background voltage distortion on the primary feeder. A source impedance corresponding to a fault current of 2kA was

assumed based upon the location of the test transformer on the distribution feeder. The actual measurements were then compared to simulations run on HarmFlo+ workstation simulation package to validate the models.

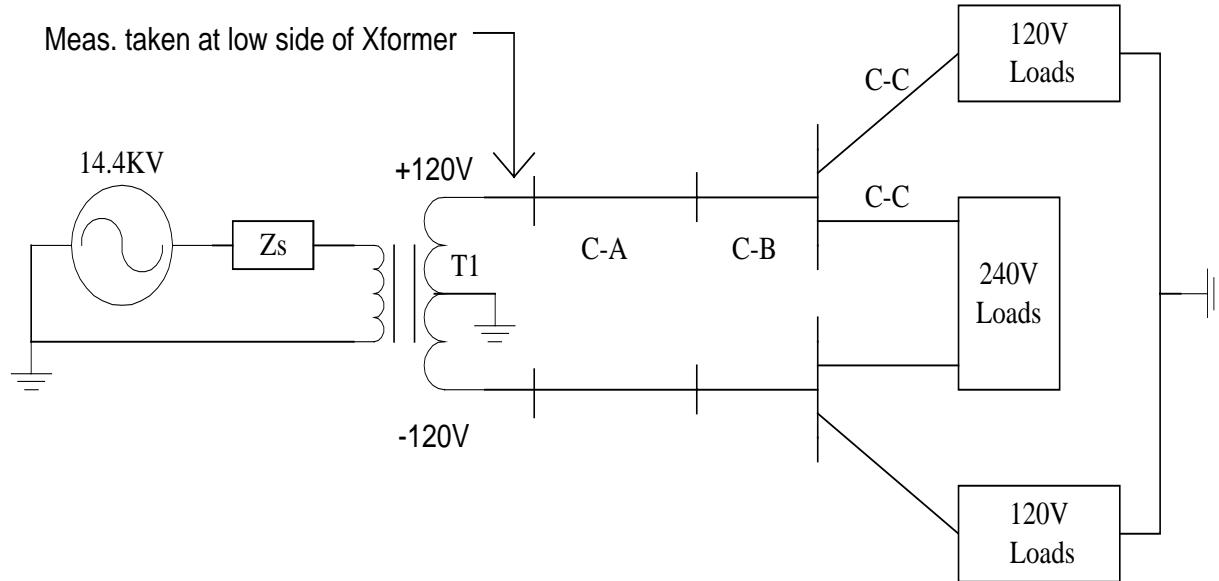


Figure 1. Feeder selected for measurements

Table A. Typical parameters for each type of conductor used in Fig.1

Type	Conductor	Length of conductor (ft.)	Impedance ($\Omega/1000$ ft.)
C-A	350 MCM Al	110	0.0628+j0.0286
C-B	4/0 Al	50	0.100+j0.041
C-C	#12 Cu	50	2.000+j0.054

Table B. Typical parameters for distribution transformer used in Fig. 1

Type	KVA	%Z	X/R
Pad-mounted	25	2.1	1.4

The case scenarios were based on the worst and best case loads in the test home. The loads with the maximum current THD in each category, such as home office, high power loads, etc., were chosen for the worst case scenario. The best case scenario included mostly the loads with low distortion in current. A marginal case scenario with a mix of the best and worst case scenarios was also performed. The specific configurations and a comparison of the actual measurements and the simulation results are provided in the sections below.

Worst Case Scenario

For the “worst case” scenario, the appliances and EV charger selected have the highest THD in their categories. A listing of the appliances chosen for this scenario is shown in Table C. The

measurements and simulations were performed with the non-linear loads and the Ford Ranger EV charger and EVSE taken separately as well as together. In all the scenarios, the X1 and X3 line currents correspond to the currents in the +120V and -120V line feeders. A comparison of the measurements and simulations is shown in Tables D and E for the above mentioned sub-cases. For case 1(c), the voltage and current waveforms for X1 are shown in Fig. 2. Detailed data for each current harmonic component are included in Appendix B.2

Table C. Worst case scenario appliances

Appliance	RMS Current (A)	THD(%)
Television	1.3	96.0
Stereo	1.2	78.8
Computer	1.6	111.7
Drill	2.0	21.6
Ford Ranger	23.4	5.2

Table D. Comparison of current measurements and simulation results

	Appliances included	X1 Line Current				X3 Line Current			
		Meas. (A)	Sim. (A)	Meas. THD %	Sim. THD %	Meas. (A)	Sim. (A)	Meas. THD %	Sim. THD %
Case 1(a)	Ford Ranger EV Charger w/EVSE	23.3	23.2	5.3	5.5	23.5	23.5	5.4	5.5
Case 1(b)	Television, Stereo, Computer, Drill	4.7	5.9	55.9	67.2	0.0	0.0	0.0	0.0
Case 1(c)	Television, Stereo, Computer, Drill, Ford Ranger EV Charger w/EVSE	27.4	27.3	7.5	9.6	23.5	23.2	5.5	5.6

Table E. Comparison of voltage measurements and simulation results

	Appliances included	Secondary Line Voltage (V)		Secondary Line Voltage THD %	
		Meas.	Sim.	Meas.	Sim.
Case 1(a)	Ford Ranger EV Charger w/EVSE	248.0	246.7	1.6	1.5
Case 1(b)	Television, Stereo, Computer, Drill	124.2	124.0	1.7	1.6
Case 1(c)	Television, Stereo, Computer, Drill, Ford Ranger EV Charger w/EVSE	248.4	246.8	1.7	1.6

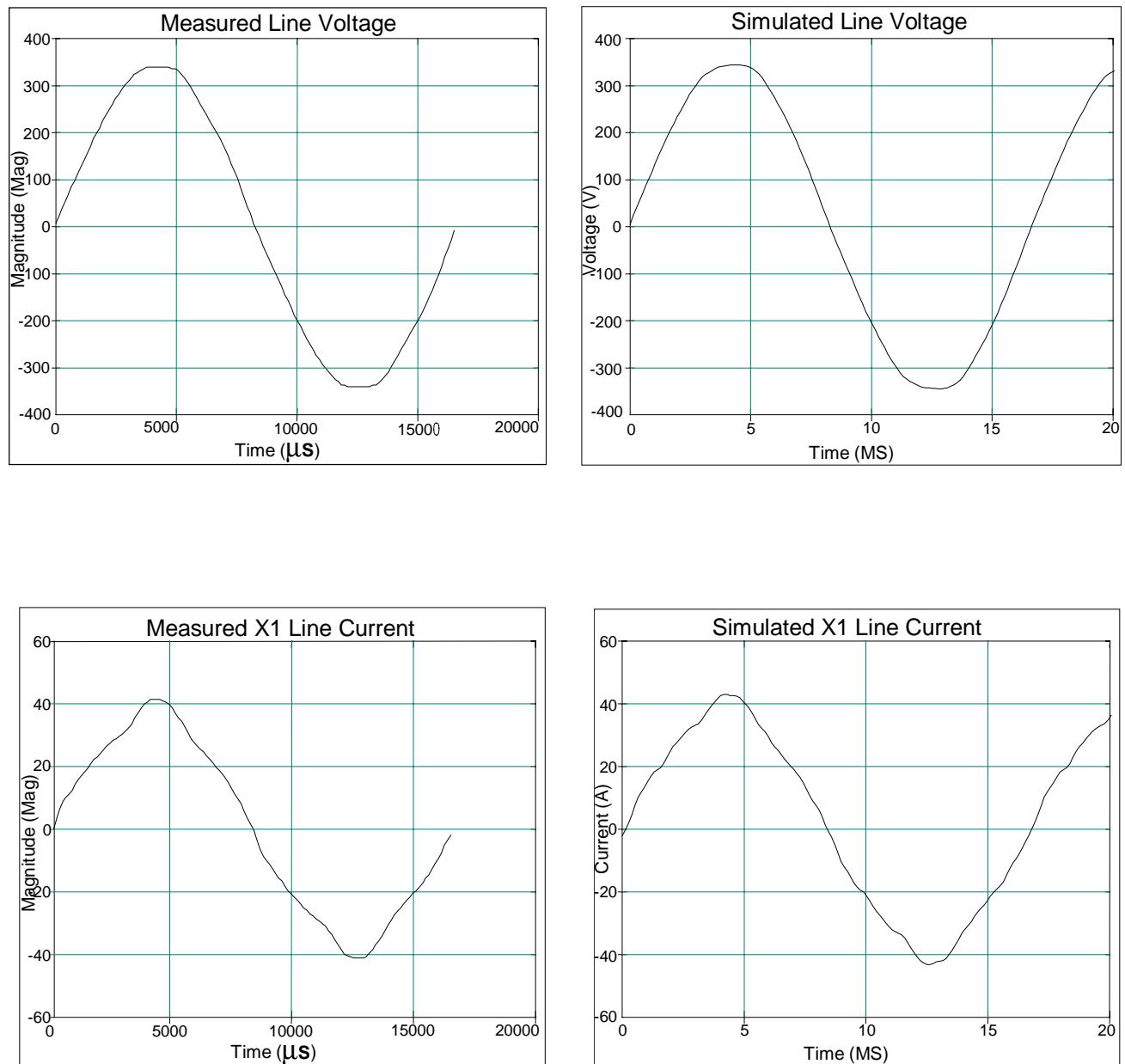


Figure 2. Current and voltage waveforms for X1 for case 1(c)

Best Case Scenario

For the “best case” scenario, the appliances selected were the ones with the lowest current THD. Two sub-case scenarios, with and without the lights included with the appliances, were studied. A listing of the appliances chosen for this scenario is shown in Table F. A comparison of the measurements and simulations is shown in Tables G and H for the above mentioned sub-cases. For

case 2(a), the voltage and current waveforms for X1 are shown in Fig. 3. Detailed data for each current harmonic component are included in Appendix B.2

Table F. Best case scenario appliances

Appliance	RMS Current (A)	THD(%)
Oven	24.7	1.8
Refrigerator	5.0	2.0
Light Bulbs - 24 of 100W each	20.4	7.4

Table G. Comparison of current measurements and simulation results

	Appliances included	X1 Line Current				X3 Line Current			
		Meas. (A)	Sim. (A)	Meas. THD %	Sim. THD %	Meas. (A)	Sim. (A)	Meas. THD %	Sim. THD %
Case 2(a)	Oven, Refrigerator, Lights	40.6	40.6	2.2	1.5	34.0	35.7	2.0	1.7
Case 2(b)	Oven, Refrigerator	26.4	25.6	2.6	1.8	30.5	30.7	2.2	1.8

Table H. Comparison of Voltage measurements and simulation results

	Appliances included	Secondary Line Voltage (V)		Secondary Line Voltage THD %	
		Meas.	Sim.	Meas.	Sim.
Case 2(a)	Oven, Refrigerator, Lights	247.5	247.0	1.7	1.5
Case 2(b)	Oven, Refrigerator	247.7	247.2	1.7	1.5

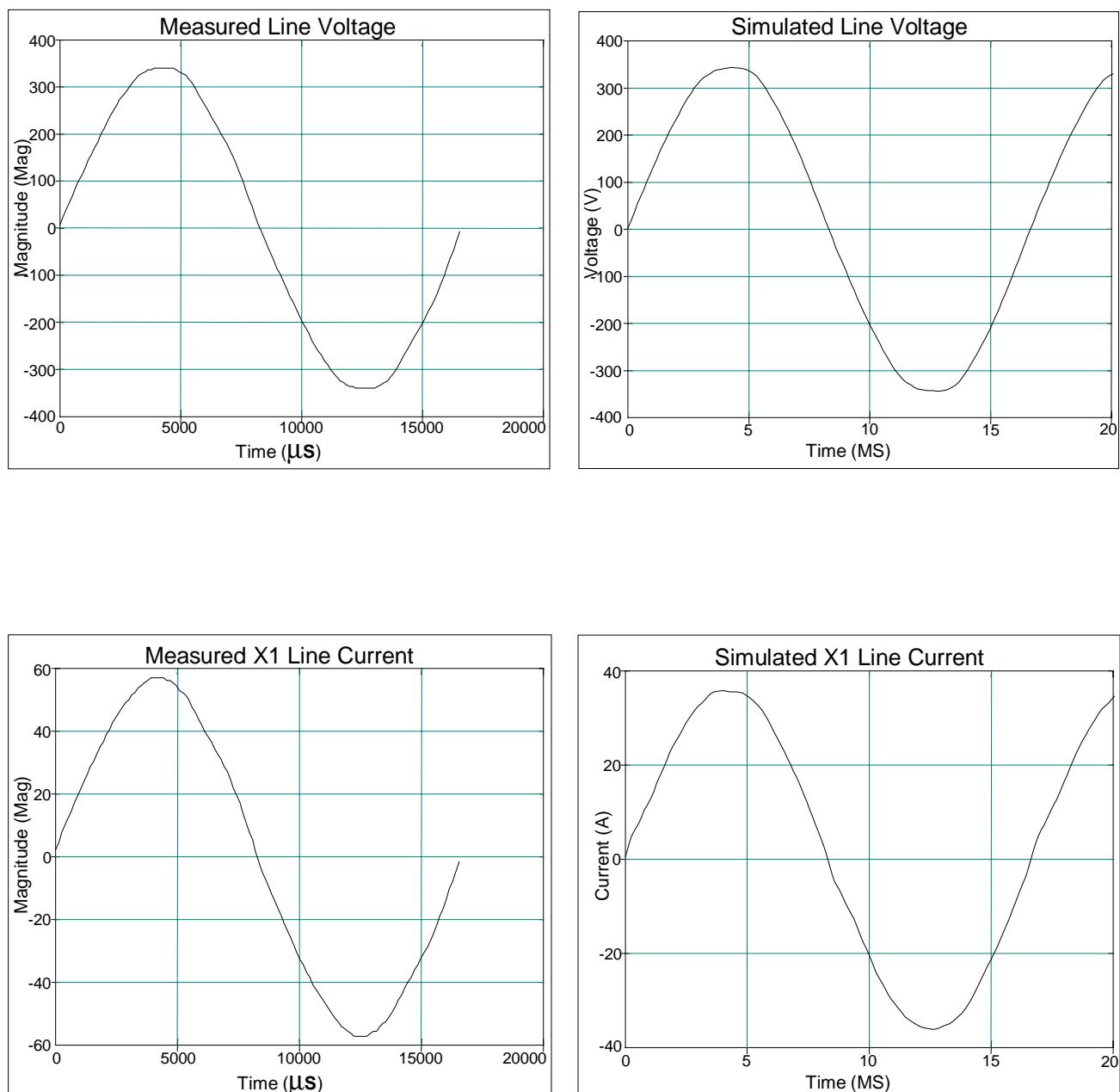


Figure 3. Current and voltage waveforms for X1 for case 2(a)

Marginal Case Scenario

For the “marginal case” scenario, the appliances and EV charger selected were a mix of the best and worst loads indicated in the previous case scenarios. This case corresponds to a “real world” case with the effect of non-linear loads and EV chargers being studied when a non-distorting load is present. A comparison of the measurements and simulations is shown in Tables I and J for the above mentioned sub-cases. For case 3(c), the voltage and current waveforms are shown in Fig. 4. Detailed data for each current harmonic component are included in Appendix B.2

Table I. Comparison of current measurements and simulation results

	Appliances included	X1 Line Current				X3 Line Current			
		Meas. (A)	Sim. (A)	Meas. THD %	Sim. THD %	Meas. (A)	Sim. (A)	Meas. THD %	Sim. THD %
Case 3(a)	Oven, Refrigerator, Ford Ranger EV Charger w/EVSE	49.8	46.5	2.7	2.9	52.3	51.5	2.9	2.7
Case 3(b)	Oven, Refrigerator, Stereo, Computer, Drill, Television, Ford Ranger EV Charger w/EVSE	53.6	50.9	4.7	5.3	52.0	51.5	2.8	2.7
Case 3(c)	Oven, Refrigerator, Lights, Ford Ranger EV Charger w/EVSE, Stereo, Drill, Television, Computer	67.1	68.4	3.3	4.0	57.1	56.3	2.5	2.5

Table J. Comparison of voltage measurements and simulation results

	Appliances included	Secondary Line Voltage (V)		Secondary Line Voltage THD %	
		Meas.	Sim.	Meas.	Sim.
Case 3(a)	Oven, Refrigerator, Ford Ranger EV Charger w/EVSE	246.4	246.0	1.6	1.5
Case 3(b)	Oven, Refrigerator, Stereo, Computer, Drill, Television	246.6	246.0	1.6	1.5
Case 3(c)	Oven, Refrigerator, Lights, Ford Ranger EV Charger w/EVSE, Stereo, Drill, Television, Computer	246.6	245.8	1.6	1.5

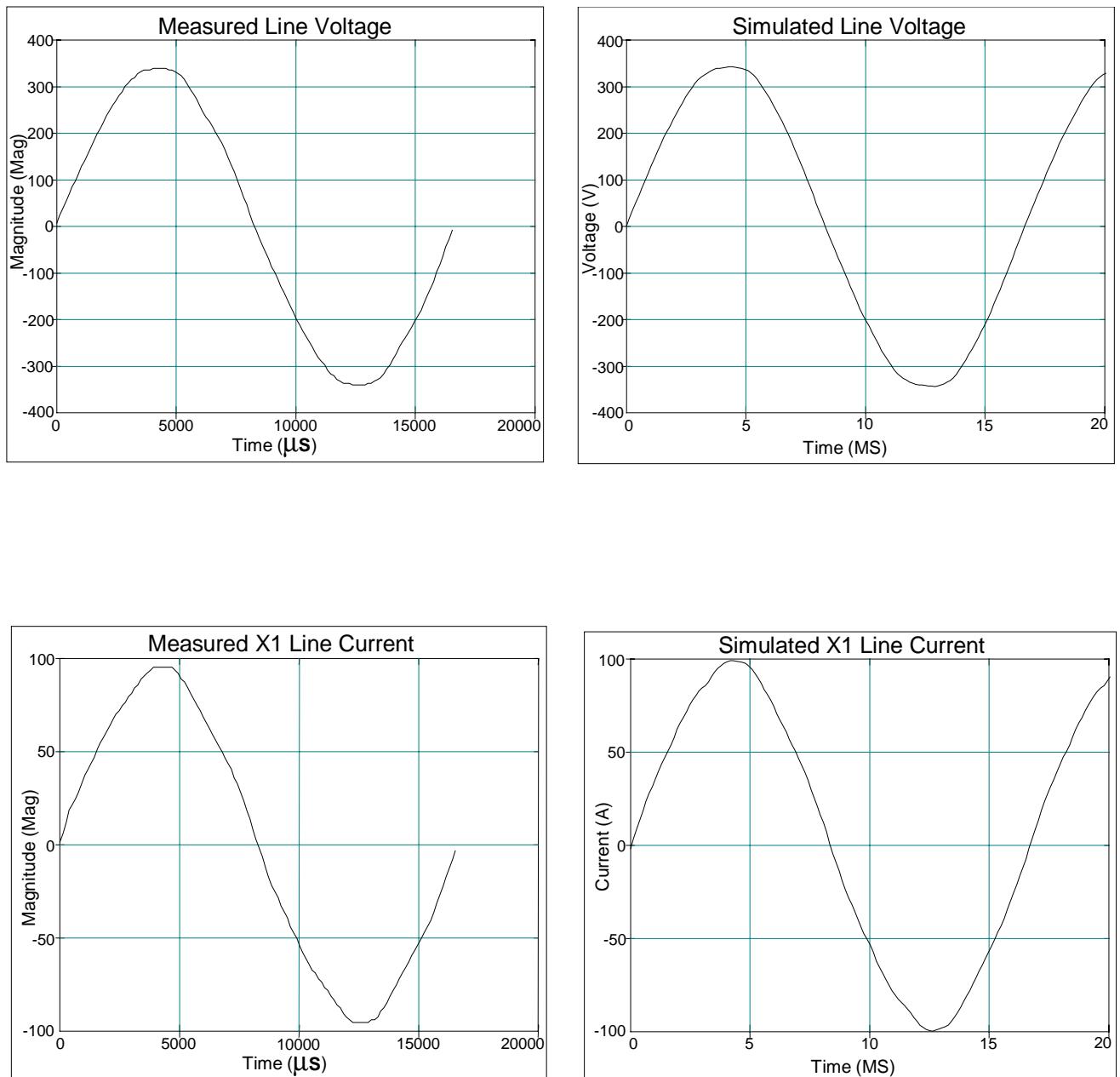


Figure 4. Current and Voltage waveforms for X1 for case 3(c)

Accuracy of model validation

The simulation results and the measurements presented in the above sections are not expected to match exactly but serve to validate the models to the extent possible taking into account the various factors involved. Some of the factors introducing variability in the measurements are:

- The inherent measurement accuracy in the Fluke41B Power Harmonics Analyzer. Error in the current and voltage measurements is less than 0.5% of the reading. Error in the individual harmonic measurements is less than 3% of the reading up to the 13th harmonic, thereafter steadily increasing up to 8% of the reading for the 31st harmonic.
- Background distortion of the high side supply voltage at the feeder introduces differences between the measurements and the simulated values. The models were created with respect to the background voltage distortion present at the time the measurements for individual appliances were taken. The background voltage distortion was different at the time when the measurements for the case scenarios were performed.
- The repeatability of the measurements introduces measurement inaccuracy. Five measurements were performed on a computer in the laboratory over a forty-five minute period using the Fluke41B Power Harmonics Analyzer. The rms current varied from 0.72 to 0.75 amps and the current THD varied from 8.1% to 9.3%.
- Loads classified as constant power loads, such as the computer, cannot be modeled as such in HarmFlo due to the unavailability of a proper model. These loads were modeled as non-linear loads leading to a certain degree of inaccuracy.
- Appliance operating cycles also influence the accuracy of the measurements to a great extent. The dishwasher, heat pump, washing machine etc., which have more than one cycle of operation, also lead to variability in the measurements. For this reason, these cycling loads were not included in the case scenarios. The data recorded in the library for these appliances was taken during the cycle with the worst current distortion.

Conclusion

The modeling of the loads characterized during Phase 1 of the project was accomplished during this phase of the project. The models created in Electrotek's HarmFlo+ software were validated by measurements taken at a test home. The case scenarios presented show close correlation between the simulated results and measured values. Further, the reasons for differences between measured and simulated results were established. This report completes Phase 2 of the project.



Third Interim Report

Secondary Distribution Impacts of Residential EV Charging



THIRD INTERIM REPORT

February 7, 2000

Project Title: Secondary Distribution Impacts of Residential EV Charging

Investigators: Dr. Ron Harley, NEETRAC, ECE Professor (Co-Principal Investigator)
Frank Lambert, NEETRAC, Program Manager (Co-Principal Investigator)
Vinod Rajasekaran, NEETRAC, ECE Graduate Research Assistant
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John Kennedy, Georgia Power Company (Project Advisor)

Abstract: This third of four interim reports documents the simulation case studies representative of the electrical service configurations of the participating utilities. An evaluation of worst and best case conditions with respect to the transformer parameters and circuit configurations was performed. The report also documents the effects of harmonic currents on line and transformer losses and transformer de-rating aspects. The absolute worst case simulation scenario resulted in a voltage THD of 5.1%, which is on the edge of the recommended limits for voltage distortion (i.e. 5%). Simulation results from all of the participating utilities are included. This report documents the successful completion of Phase III of the planned project outline.

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Third Interim Report

Abstract

This third of four interim reports documents the simulation case studies representative of the electrical service configurations of the participating utilities. An evaluation of worst and best case conditions with respect to the transformer parameters and circuit configurations was performed. The report also documents the effects of harmonic currents on line and transformer losses and transformer de-rating aspects. The absolute worst case simulation scenario resulted in a voltage THD of 5.1%, which is on the edge of the recommended limits for voltage distortion (i.e. 5%). Simulation results from all of the participating utilities are included. This report documents the successful completion of Phase III of the planned project outline.

Compilers

The process of translating utility system data into HarmFlo code can be a time-consuming and tedious process. It is possible to automate the process of generating the HarmFlo files for any case scenario given the utility data. Utility system data were provided to a Compiler Program written in PASCAL to translate the input data into HarmFlo input files. A short summary of the program and an example have been provided in Appendix C.1.

Simulation Protocol

The simulation variables were:

- EV charger type and mix
- Distribution transformer capacity (kVA) and impedance
- Conductor impedance (size and length)
- Number of customers
- Maximum demand

Worst and typical case conditions were identified for each of these variables by the participating utilities. The worst case conditions for the simulation procedure identified from the utility data were:

- EV charger with highest current THD
- Lowest transformer capacity (kVA)
- Highest transformer impedance
- Highest conductor impedance
- Maximum number of customers
- Maximum demand

All case scenarios were simulated with and without the EV charger to study the system performance on introduction of chargers. Due to diversity effects leading to phase cancellation of the harmonic currents, the changes in voltage THD with the addition of chargers cannot be attributed only to the chargers. Rather, the changes in voltage THD signify the effects of chargers interacting with other home appliances in a real world situation.

A study of the line and transformer losses was also undertaken for the various case scenarios. In general, a transformer in which the current distortion exceeds 5% is usually considered for de-rating for harmonics. The “IEEE recommended practice for establishing transformer capability when supplying non-sinusoidal load currents” as defined in IEEE Std. C57.110-1998 was used for de-rating the transformers. The Harmonic Loss Factor (F_{HL}) can be defined solely in terms of the harmonic currents as follows:

$$F_{HL} = \frac{(I_h^2 \times h^2)}{I_h^2} \quad (3.1)$$

Then, in terms of the Harmonic Loss Factor, the de-rating of the transformer can be derived to be

$$D = \sqrt{\frac{1 + P_{EC-R}}{1 + F_{HL} \times P_{EC-R}}} \text{ (per unit)} \quad (3.2)$$

where P_{EC-R} = eddy current loss factor (in terms of the conduction loss)

h = harmonic number

I_h = harmonic current

A typical per unit eddy current loss factor of 8% was assumed for performing the calculations. The 8% value is based upon industry experience.

Simulation Results

This section presents the results of the three different simulation case scenarios. The three scenarios are:

- Worst Case Scenario
- Marginal Case Scenario
- Typical Case Scenario

A comparative study of the simulation parameters for the three cases is shown below in Table A.

Table A. Comparison of Simulation Parameters

	Worst	Marginal	Typical
EV Charger Penetration %	100%	100%	50%
EV Charger Current THD	17.0 %	14.3 %	14.3 %
Distribution Service Transformer	15 kVA %R=4.5,%X=4.0	15 kVA %R=4.5,%X=4.0	50 kVA %R=0.9,%X=1.1
Conductor Used	#2Al Triplex	#2 Al Triplex	350 Al Triplex
Length of conductor	120 ft.	120 ft.	75 ft.
No. of customers	2	2	4
Total Load	25.7 kW	24.7 kW	40 kW
% Loading	172 %	165 %	76 %

Worst Case Scenario

For the “worst case” scenario an EV charger model was constructed from the IEC 1000-3-2 recommended limits for harmonic currents for equipment. This simulated charger has a current THD of 17.3%. These limits have been adopted in the form of an IWC Record of Consensus (ROC) recommendation for EV charger current distortion. The recommended limits place absolute limits on the harmonic currents as a percentage of the fundamental. The current waveform and its harmonic spectrum are shown in Fig 1. The worst case scenario assumed that all EV owners used the same EV charger thus removing the effects of harmonic phase cancellation.

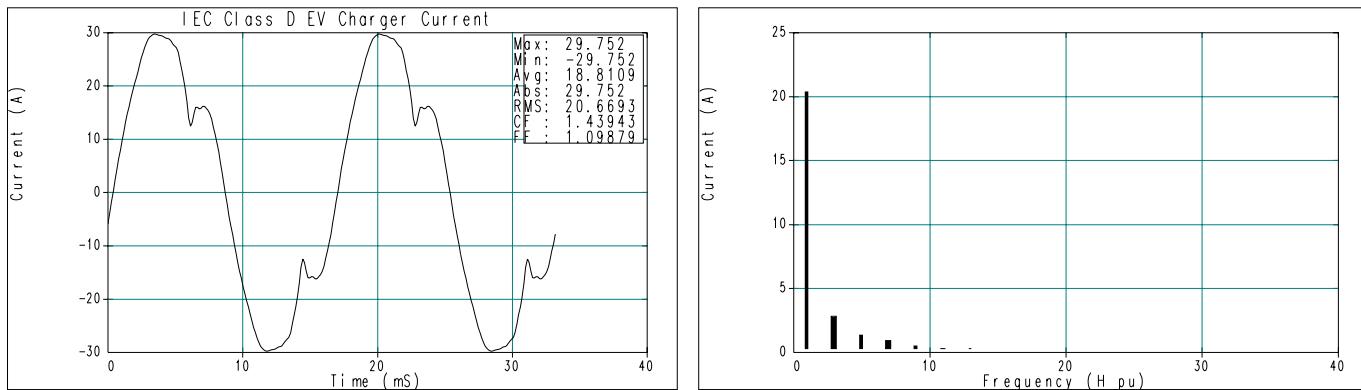


Fig. 1. IEC Class-D EV Charger Current Waveform and Spectrum

The worst case conditions for the other simulation parameters provided by the utility participants is shown in Table B. The results obtained for the various utilities for their worst case scenarios is shown in Table C.

Table B. Utility Data for Worst case conditions

	Utility A	Utility B	Utility C	Utility D [†]	Utility E	Utility F
Distribution Transformer	15kVA %Z=6% X/R=0.9	333 kVA %Z=3.7% X/R=3.6	45 kVA %Z=2% X/R=1.0	100 kVA %Z=2.2% X/R=1.9	15 kVA %Z=2% X/R=1.1	25 kVA %Z=4% X/R=1.0
Line conductor	#2 Al Triplex	R=143.3mΩ X=25.2 mΩ	2/0 Cu	#1/0 Al Triplex	#4 Al	1/0 Al
Length of conductor	75 ft.	-	120 ft.	300 ft.	80 ft.	100 ft.
Number of customers	2	40	2	8	5	4
Type of loading	Residential	Residential	Commercial	Residential	Residential	Residential
Maximum Demand	172%	183%	95%	50%	145%	161%
Background Voltage Distortion	1.5%	3.4%	1.5%	1.5%	1.5%	1.5%
EV Charger Current THD %	17.3%	17.3%	17.3%	55.0%	17.3%	17.3%
Single/Three Phase	Single	Single	Three	Single	Single	Single

[†] Utility D requested all simulations be performed with an EV charger current THD of 55%.

Table C. Worst Case Utility Simulation Results

	Utility A	Utility B	Utility C*	Utility D	Utility E	Utility F
X1 Line Current	98.4 A 8.0 %THD	2.53 kA 6.3 %THD	95.4 A 35.0 %THD	185.7 A 21.8 %THD	98.6 A 8.2 %THD	156.5 A 5.0 %THD
X3 Line Current	94.1 A 8.3 %THD	2.57 kA 6.5 %THD	95.7 A 39.3 %THD	213.2 A 20.6 %THD	75.3 A 11.7 %THD	161.6 A 8.0 %THD
Secondary Line Voltage	217.0 V 5.1 %THD	242.8 V 4.1 %THD	207.4 V 1.9 %THD	238.3 V 2.0 %THD	233.3 V 2.5 %THD	237.6 V 3.0 %THD
Line Losses	45.0 W	48.7 kW	436.2 W	340.8 W	135.4 W	264.0 W
Transformer Losses	800.8 W	10.6 kW	197.9 W	167.4 W	546.3 W	1.8 kW
Harmonic Loss Factor	1.2	1.1	2.7	2.2	1.1	1.1
Transformer De-rating	0.99	1.0	0.94	0.96	1.0	1.0
Incremental Voltage THD due to introduction of chargers	2.5%	0.8%	0.0%	0.4%	0.7%	0.7%

* Utility C was a three-phase system. X1 and X3 in this case refer to Phase A and Phase C.

An “absolute worst” case scenario was created from the worst case conditions provided by the various utilities by selecting worst values from data provided by all utilities. The simulation parameters for the worst case scenario are reported in Table D. The field configuration used for the worst case is shown in Fig.2. The source voltage was assumed to have a background voltage distortion of 1.5%. The background source voltage used was derived from the measurements taken for model validation at one of the test homes during Phase II of the project. The mix of appliances used for the worst case scenario are shown in Table E. The results obtained are shown in Fig 3 and Table F. The system performance with regard to line and transformer losses is shown in Table G.

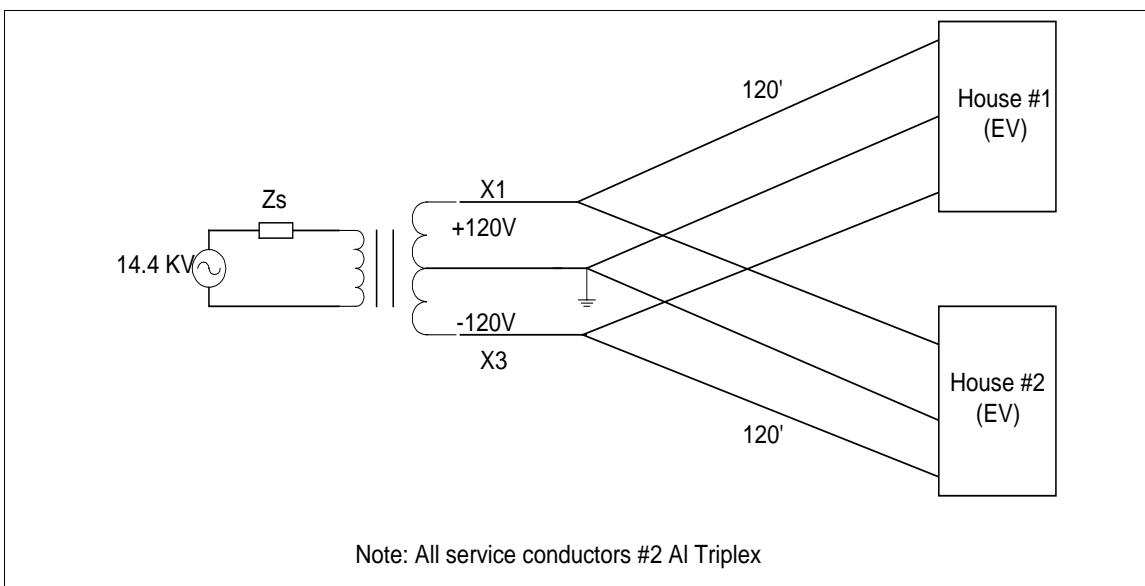


Fig. 2. Field Site Configuration for Absolute Worst Case Simulation

Table D. Absolute Worst Case Simulation Parameters

	Value
EV Charger	17% current THD
Distribution Service Transformer	15 kVA %R=4.5,%X=4.0
Conductor Used	#2 Al Triplex
Length of conductor	120 ft.
No. of customers	2

Table E. Appliances Used In Simulation

House #1		House #2	
Appliance	Load (kW)	Appliance	Load (kW)
Refrigerator	0.6	Refrigerator	0.6
Air Conditioner	2.3	Air conditioner	2.3
Microwave	1.3	Toaster	0.8
Hair Dryer	1.1	VCR	0.1
Computer	0.1	Television	0.1
Dryer	4.8	Washing Machine	0.4
EV charger (IEC)	5.6	EV Charger (IEC)	5.6
Total Load	15.8 kW	Total Load	9.9 kW

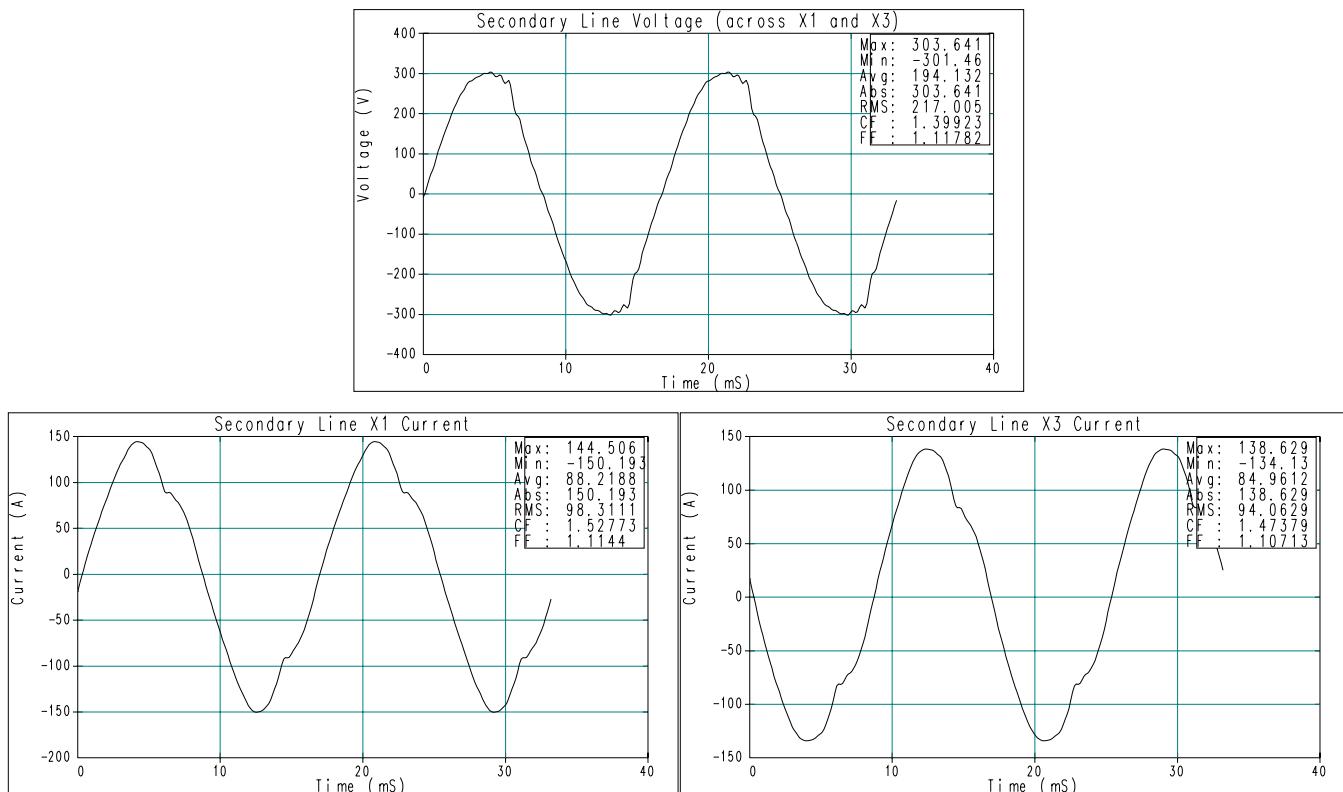


Fig 3. Absolute Worst Case Simulation Results

Table F. Absolute Worst Case Simulation Results

	X1 Line Current		X3 Line Current		Sec. Line Voltage (V)	Sec. Line Voltage THD (%)
	Sim. (A)	THD (%)	Sim. (A)	THD(%)		
Without Charger	61.2	8.6	56.7	5.4	225.7	2.6
With Charger	98.3	8.0	94.1	8.3	216.7	5.1

Table G. Line and Transformer Losses (Absolute Worst Case)

	Line Losses (W)	Transformer Winding Losses (W)	Harmonic Loss Factor	Transformer De-rating
Without Charger	18.5	299.1	1.1	1.0
With Charger	45.0	800.8	1.2	0.99

Utility “A” had the maximum voltage distortion of 5.1% with the introduction of chargers while the rest of the utilities did not have significant changes in voltage THD. Utility “A” had the worst transformer impedance resulting in higher THD. Utilities “C” and “D” were lightly loaded and had average transformer impedances resulting in negligible changes to voltage THD. Utility “B” had a marginal increase in voltage THD by 0.8%.

Marginal Case Scenario

For the marginal case scenario a commercial charger with the highest current THD namely the Honda EV charger with 14.3% THD was used as compared to the worst case scenario charger with 17.3% current THD. The other parameters namely the system data and the appliances remained the same, as in the worst case scenario. The current waveform and its spectrum are shown in Fig 4. The simulation results for the various utilities have been summarized in Table I. An “absolute marginal” case scenario was constructed similar to the “absolute worst” case with the Honda EV charger incorporated into the simulations. The results have been summarized in Tables J and K and Fig. 4.

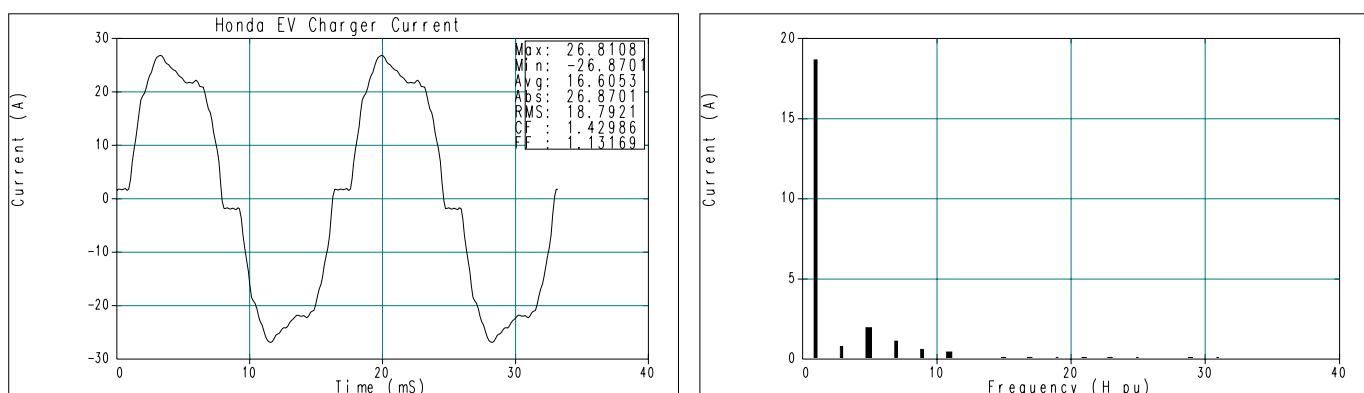
**Fig 4. Honda EV Charger Current Waveform and Spectrum**

Table H. Utility Data for Marginal Case Conditions

	Utility A	Utility B	Utility C	Utility D	Utility E	Utility F
Distribution Transformer	15 kVA %Z=6% X/R=0.9	333 kVA %Z=3.7% X/R=3.6	45 kVA %Z=2% X/R=1.0	100 kVA %Z=2.2% X/R=1.9	15 kVA %Z=2% X/R=1.1	25 kVA %Z=4% X/R=1.0
Line Conductor	#2 Al Triplex	R=143.3mΩ X=25.2 mΩ	2/0 Cu	#1/0 Al Triplex	#4 Al	1/0 Al
Length of Conductor	75 ft.	-	120 ft.	200 ft.	80 ft.	100 ft.
Number of Customers	2	40	2	8	5	4
Type of Loading	Residential	Residential	Commercial	Residential	Residential	Residential
Maximum Demand	172%	189%	95%	116.5%	138%	157%
Background Voltage Distortion	1.5%	3.4%	1.5%	1.5%	1.5%	1.5%
EV Charger Current THD	14.3%	14.3%	14.3%	55.0%	14.3%	14.3%
Single/Three Phase	Single	Single	Three	Single	Single	Single

Table I. Marginal Case Utility Simulation Results

	Utility A	Utility B	Utility C*	Utility D	Utility E	Utility F
X1 Line Current	95.0 A 6.2 % THD	2.46 kA 5.2 % THD	94.3 A 37.4 % THD	405.7 A 9.8 % THD	94.6 A 6.8 % THD	152.5 A 4.5 % THD
X3 Line Current	90.7 A 5.6 % THD	2.49 kA 5.3 % THD	94.1 A 39.6 % THD	430.7 A 7.5 % THD	71.1 A 9.1 % THD	157.5 A 7.2 % THD
Secondary Line Voltage	217.7 V 4.5 % THD	242.9 V 3.1 % THD	207.4 V 1.9 % THD	236.6 V 1.9 % THD	233.6 V 2.1 % THD	238.0 3.0 % THD
Line Losses	42.1 W	46.1 kW	412.5 W	1.8 kW	123.2 W	254.1 W
Transformer Losses	745.2 W	10.0 kW	187.2 W	541.3 W	516.1 W	1.8 kW
Harmonic Loss Factor	1.1	1.1	2.9	1.1	1.2	1.1
Transformer De-rating	1.0	1.0	0.94	1.0	0.99	1.0
Incremental Voltage THD Due to Introduction of Chargers	1.9%	-0.2%	0.0%	0.1%	0.3%	0.7 %

* Utility C was a three-phase system. X1 and X3 in this case refer to Phase A and Phase C.

Table J. Absolute Marginal Case Simulation Results

	X1 Line Current		X3 Line Current		Sec. Line Volt.(V)	Sec. Line Voltage THD(%)
	Sim. (A)	THD (%)	Sim. (A)	THD (%)		
Without Charger	61.0	8.6	56.6	5.4	225.6	2.6
With Charger	94.9	6.3	90.6	5.7	217.5	4.5

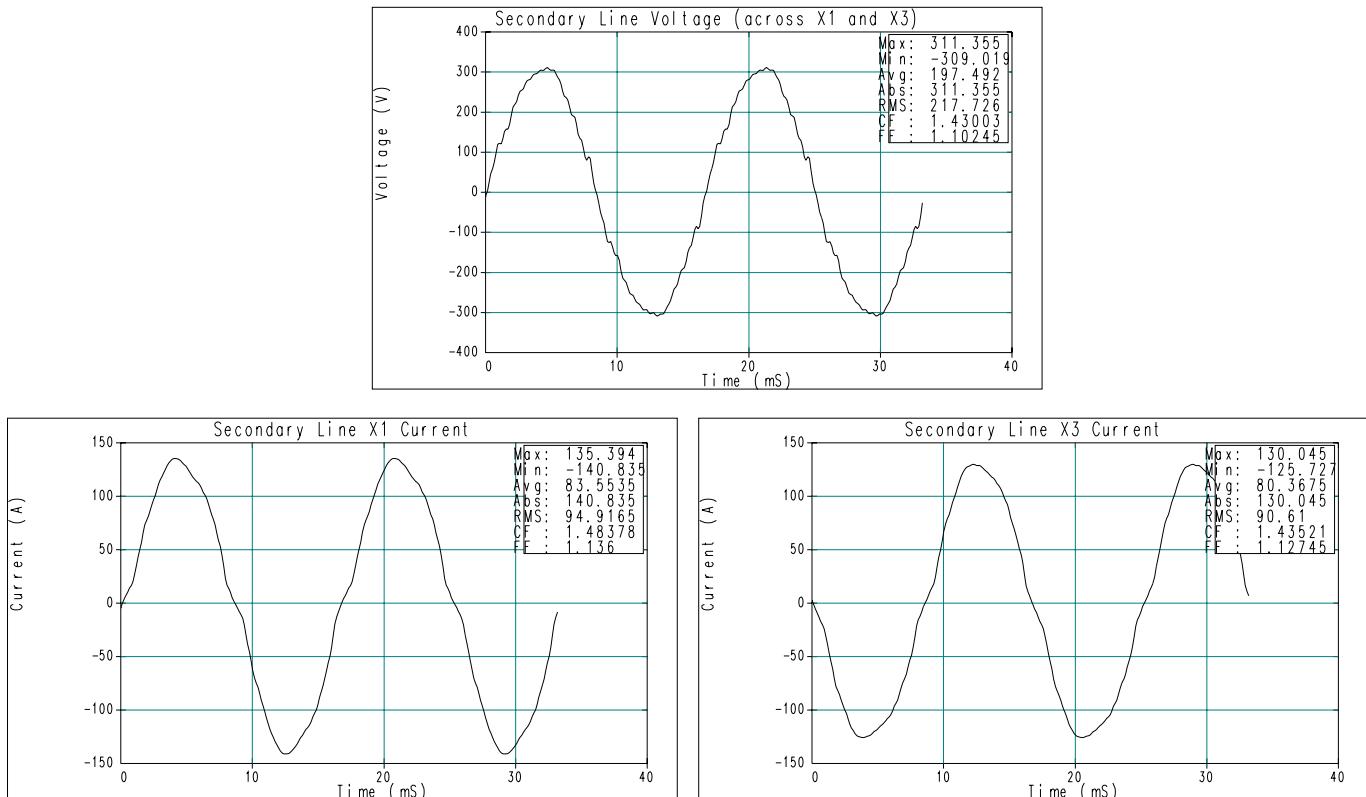


Fig 5. Absolute Marginal Case Simulation Results

Table K. Line and Transformer Losses (Absolute Marginal Case)

	Line Losses (W)	Transformer Winding Losses (W)	Harmonic Loss Factor	Transformer De-rating
Without Charger	18.5	299.1	1.1	1.0
With Charger	42.1	745.2	1.1	1.0

Similar results were obtained for the marginal case simulations as the worst case simulations with a lessening of the voltage THD as an EV charger with lesser current THD was used for the simulations. It was also noticed that the voltage THD in the case of Utility “B” was

actually reduced with the introduction of EV chargers. This can be attributed to the harmonic cancellation effect with the introduction of non-linear loads (EV chargers). Utilities “C” and “D” did not have significant increases in voltage THD with the introduction of the chargers.

Typical Case Scenario

The parameters and results obtained for the typical case simulations for each individual utility are shown in Tables L and M. A typical case scenario was also simulated with data selected from the utility transformer and service parameters. The Honda EV charger was used for the simulations. Typical transformer and service parameters were used for the case scenarios and are shown in Table N. The appliances used for the typical case scenario simulation are shown in Table O. The simulation results are shown in Tables P and Q.

Table L. Utility Data for Typical Case Conditions

	Utility A	Utility B		Utility C	Utility D	Utility E	Utility F
		Under-ground	Overhead				
Distribution Transformer	37.5 kVA %Z=1.4% X/R= 0.8	50 kVA %Z=1.8% X/R=1.1	37.5 kVA %Z=1.8% X/R=1.1	100 kVA %Z=2.2% X/R=1.9	300 kVA %Z=4% X/R=1.0	75 kVA %Z=2% X/R=1.1	75 kVA %Z=2% X/R=1.0
Line Conductor	#4/0 Al Triplex	R=19.1mΩ X=19.7mΩ	R=19.1mΩ X=19.7mΩ	#1/0 Al Triplex	2/0 Cu	#2 Al	4/0 Al
Length of Conductor	75 ft.	-	-	100 ft.	30 ft.	80 ft.	100 ft.
No. of Customers	4	20	15	8	1	15	16
*Type of Loading	R	R	R	R	C	R	R
Maximum Demand	91 %	156%	150%	78%	42%	143%	146%
Background Voltage THD	1.5%	3.4%	3.4%	1.5%	1.5%	1.5 %	1.5%
EV Charger THD %	14.3%	14.3%	14.3%	55.0%	14.3%	14.3%	14.3%
Single/Three Phase	Single	Single	Single	Single	Three	Single	Single

* Type of Loading – R – Residential, C - Commercial

Table M. Typical Case Utility Simulation Results

	Utility A	Utility. B		Utility C*	Utility D	Utility E	Utility F
		Under-ground	Overhead				
X1 Line Current	137.0 A 6.0 %THD	319.4 A 10.1 %THD	257.7 A 9.2 %THD	281.9 A 17.4 %THD	450.2 A 46.1%THD	421.4 A 5.9 %THD	448.2 A 8.4 %THD
X3 Line Current	134.9 A 5.3 %THD	305.1 A 11.6 %THD	248.7 A 10.5 %THD	307.4 A 13.8 %THD	526.8 A 54.2 %THD	396.8 A 9.4 %THD	466.6 A 8.7 %THD
Secondary Line Voltage	237.3 V 1.6 %THD	243.9 V 3.7 %THD	239.3 V 3.7 %THD	237.6 V 2.1 %THD	206.9 V 2.7 %THD	233.9 V 1.9 %THD	238.5 V 2.1 %THD
Line Losses	115.5 W	277.4 W	228.9 W	902.4 W	1.7 kW	613.2 W	1.9 kW
Transformer Losses	319.3 W	1.4 kW	1.2 kW	262.0 W	1.1 kW	1.1 kW	1.7 kW
Harmonic Loss Factor	1.1	1.4	1.3	1.5	4.2	1.2	1.2
Transformer De-rating	1.0	0.99	0.99	0.98	0.90	0.99	0.99
Incr. Voltage THD Due to Chargers	0.1%	-0.3%	-0.2%	0.3%	0.0%	0.0%	0.3%

* Utility C was a three-phase system. X1 and X3 in this case refer to Phase A and Phase C.

Table N. Typical Case Simulation parameters

	Value
Distribution Service Transformer	50 kVA
	%R=0.9,%X=1.1
Conductor Used	350 Al Triplex
Length of conductor	75 ft.
No. of customers	4

Table O. Appliances Used In Simulation

	Appliance	Load (kW)
House #1	Refrigerator	0.6
	Air Conditioner	3.5
	Lights	0.3
	Microwave	1.3
	Computer	0.1
	Hair Dryer	1.1
	EV Charger (Honda)	5.1
	Total Load	12.0 kW
House #2	Refrigerator	0.6
	Air conditioner	3.5
	Lights	0.3
	VCR	0.1
	Television	0.1
	EV Charger (Honda)	5.1
	Total Load	9.7 kW
House #3	Refrigerator	0.6
	Air Conditioner	3.5
	Lights	0.3
	Washing Machine	0.4
	Dryer	4.8
	Coffee Maker	1.0
	Total Load	10.4 kW
House #4	Air Conditioner	3.5
	Lights	0.3
	Stereo	0.1
	CD Player	0.1
	Toaster	0.8
	Microwave	1.3
	Refrigerator	0.6
	Total Load	6.7 kW
	Total Load	38.3 kW

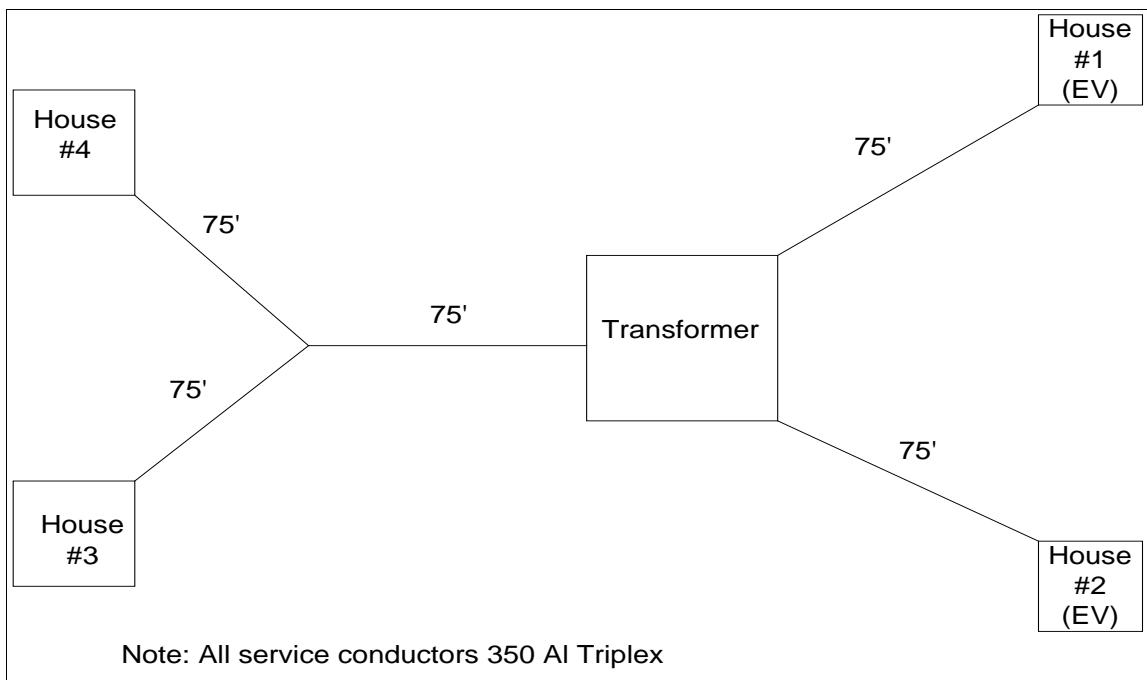


Fig. 6. Field Configuration for Typical Case Simulation

Table P. Typical Case Simulation Results

	X1 Line Current		X3 Line Current		Sec. Line Volt.(V)	Sec. Line Voltage THD(%)
	Sim. (A)	THD (%)	Sim. (A)	THD (%)		
Without Charger	113.8	9.0	111.6	6.8	238.2	1.5
With Charger	153.8	6.4	151.6	5.7	237.7	1.5

Table Q. Line and Transformer Losses (Typical Case)

	Line Losses (W)	Transformer Winding Losses (W)	Harmonic Loss Factor	Transformer De-rating
Without Charger	95.6	167.8	1.1	1.0
With Charger	125.3	337.1	1.1	1.0

In the typical case simulations the introduction of EV chargers did not result in a significant increase in THD for any of the six utilities. This clearly indicates that the introduction of chargers in a typical environment would not lead to a significant increase in THD.

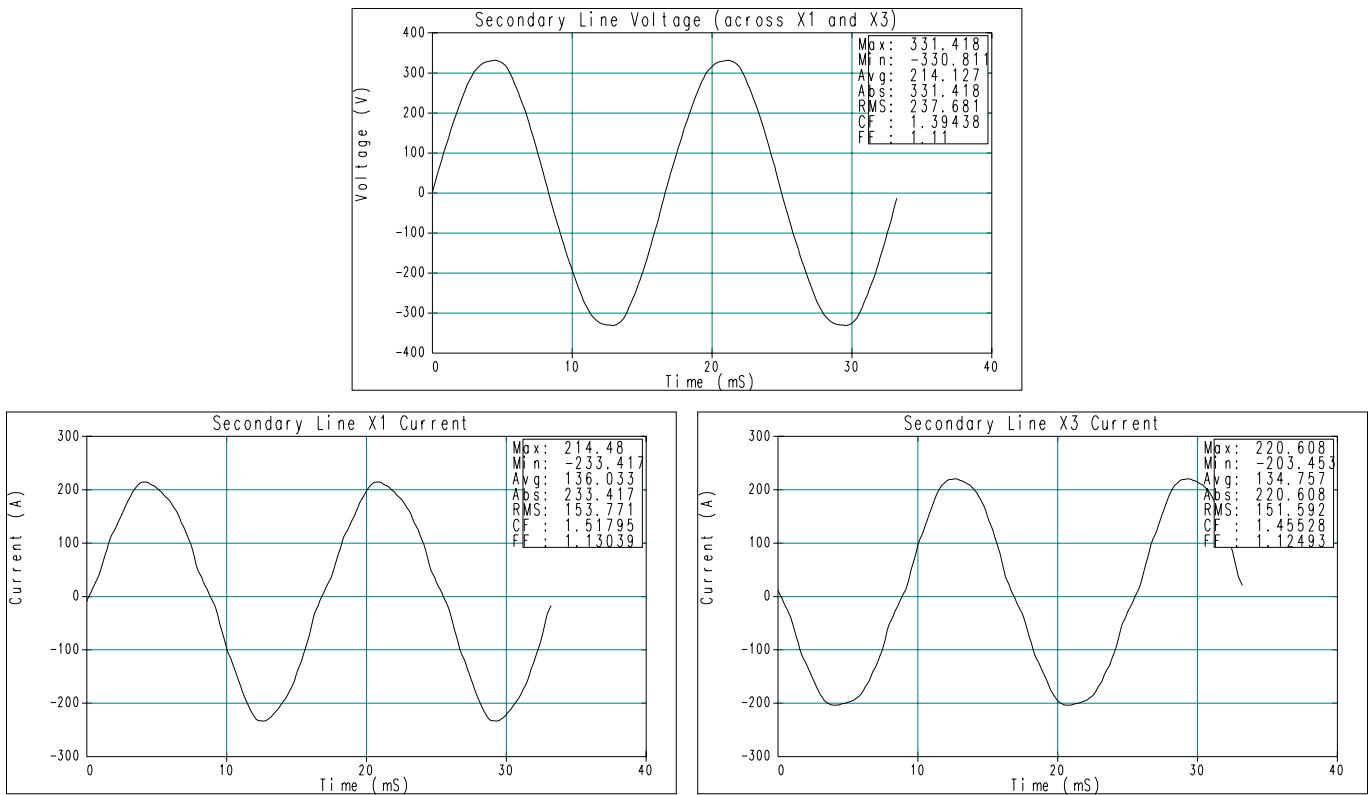


Fig 7. Typical Case Simulation Results

Conclusion

Simulation case studies of the utility service configurations were accomplished. A statistically significant evaluation of worst case service configurations has been performed. It is impossible to evaluate all possible combinations of appliances for predicting the exact worst case performance of the system. The simulation case studies performed are not intended to be complete in all respects but rather serve as valid indicators about the performance of the system under normal and stressed operating conditions. The transformer winding / line losses and transformer de-rating aspects due to the increase in harmonic currents have also been evaluated. It is noted that the de-rating of the transformer remains the same, while the line and transformer winding losses increase with the introduction of the EV chargers.

It can be seen from the simulation results that the EV chargers do not give rise to excessive voltage THD. Rather, as the penetration of EV chargers increases, loading issues will arise before excessive voltage distortion is noticed. This report completes Phase III of the project.



Fourth Interim Report

Secondary Distribution Impacts of Residential Electric Vehicle Charging



FOURTH INTERIM REPORT

April 2000

Project Title: Secondary Distribution Impacts of Residential Electric Vehicle Charging

Investigators: Dr. Richard M. Bass, NEETRAC, ECE Professor (Principal Investigator)
Dr. Ron Harley, NEETRAC, ECE Professor (Co-Principal Investigator)
Frank Lambert, NEETRAC, Program Manager (Co-Principal Investigator)
Vinod Rajasekaran, NEETRAC, ECE Graduate Research Assistant
Jason Pierce, NEETRAC, ECE Graduate Research Assistant
John Kennedy, Georgia Power Company (Project Advisor)

Field Test Utilities: Pacific Gas and Electric Company
Sacramento Municipal Utility District
Southern California Edison

Abstract: This last of four interim reports documents the field site studies performed jointly by three participating utilities and NEETRAC. The measurements at the three field sites were carried out over a month and are archived in this report. Simulation of one of the test sites was performed to compare the actual field data with the simulation of the models earlier developed. The field data and the simulation results for the voltage THD match within 2.9%, thus validating the simulation process. The absolute worst case recorded voltage THD was 4.1%, which is below IEEE's 519 recommended 5% limit for voltage distortion. The field site data confirm the results reported in the Third Interim Report, that commercial EV chargers engineered to IWC guidelines do not generate excessive voltage THD on the secondary of the transformer. A summary of the worst case conditions in each of the three system configurations is also reported. Temperature variation on the transformer due to EV charging was also studied in one field site. This report documents the completion of the last phase of the planned project outline.

Memorial: This project was initiated and directed by Dick Bass until his tragic death in an auto accident on April 14th, 1999. Bass received his B.E.E. and M.S.E.E. in 1982 and 1983, respectively, from Georgia Tech and earned his Ph.D. from the University of Illinois at Urbana-Champaign in 1990. In 1990, Bass returned to Tech as an assistant professor in electric power and was promoted to associate professor in 1997. During the 1996 Olympics, he and his students and colleagues studied the technologies and electrical distribution impacts of the Olympic Village electric vehicle (EV) transportation system. He was an active participant in the Distribution, Load Management, and Power Quality Committee of the IWC and is sorely missed.

Secondary Distribution Impacts of Residential EV Charging

Fourth Interim Report

Abstract

This last of four interim reports documents the field site studies performed jointly by three participating utilities and NEETRAC. The measurements at the three field sites were carried out over a month and are archived in this report. Simulation of one of the test sites was performed to compare the actual field data with the simulation of the models earlier developed. The field data and the simulation results for the voltage THD match within 2.9%, thus validating the simulation process. The absolute worst case recorded voltage THD was 4.1%, which is below IEEE's 519 recommended 5% limit for voltage distortion. The field site data confirm the results reported in the Third Interim Report, that commercial EV chargers engineered to IWC guidelines do not generate excessive voltage THD on the secondary of the transformer. A summary of the worst case conditions in each of the three system configurations is also reported. Temperature variation on the transformer due to EV charging was also studied in one field site. This report documents the completion of the last phase of the planned project outline.

IWC Guidelines

The National Electric Vehicle Infrastructure Working Council (IWC) Record of Consensus (ROC) (Ref: Electric Power Research Institute's EPRI BR-107842, www.epri.com) serves to document agreements developed through the IWC between automobile manufacturers and the utility industry on electric vehicle infrastructure. Some of the primary guidelines of the IWC pertinent to this analysis are:

- The minimum total power factor for EV charging is recommended to be 95% as measured at full-rated power.
- The maximum value for total current harmonic distortion for EV charging is recommended to be $\leq 20\%$ at full rated power as measured into a resistive load.
- The maximum value for current distortion at each harmonic frequency for Level 2 charging is recommended to be as specified in International Electrotechnical Committee (IEC) 1000-3-4. (Ref: IEC/TS 61000-3-4 Electromagnetic compatibility (EMC) - Part 3-4: Limits-Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A).

Field Site Summary

Field test sites were established by three of the participating utilities on their system. A distribution feeder, which is a likely candidate for EV penetration, was identified by each of the three utilities. Reliable Power Meters' (RPM) Power Recorder system was placed to monitor the distribution transformer secondary. The RPM monitors were chosen for data capture because all of the participating utilities had the model, which precluded the necessity of purchasing new monitors. Additional monitoring equipment was also placed at individual houses, splice boxes connecting the individual feeders to the houses, and at the chargers. Data collected from the three sites over a month have been archived and presented in Appendices D.1-D.3.

The field sites can be broadly classified into two classes:

- Residential (Utilities B and E)
- Commercial (Utility C)

The references to Utilities B, C and E are made in the same basis as was done in the earlier phases of this project. A comparison of the field site configurations is provided below in Table A.

Table A. Comparison of Field Site Configurations

	Utility B	Utility E	Utility C
EV Charger Penetration (%)	67 %	8 %	N/A*
Distribution Service Transformer	50 kVA %Z=2.2 %R=1.5, %X=1.7	50 kVA %Z=1.8	150 kVA %Z =2.3
Secondary Conductor Used	350 A1	350 A1	350 Cu
Service Conductor Used	4/0 A1	#2 A1	2/0 Cu
Average Length of conductor	100 ft.	55 ft.	15 ft.
No. of customers	6	16	N/A*
Type of customer	Residential	Residential	Commercial

* Utility C test site was a parking garage with commercial office space.

Benchmarking

The monitoring equipment was benchmarked with NEETRAC's RPM Power Recorder. Voltage and current waveforms were sampled with a 14 bit analog to digital converter at a rate providing 128 sampled points per cycle at 60 Hz. The RPM Power Recorder was configured in each case to average the sampled data and record the data every 5 minutes. The RPMs are calibrated to make voltage measurements with a precision of 1% of full scale.

The benchmarking was carried out over a 24-hour period and not over the entire testing period. The benchmarking dates for the utilities are provided in Table B along with the dates of the entire testing process. The absolute values of the current THD and voltage THD, at the time when maximum deviation between the benchmark data and field data was observed, are shown in Table B. The percentage difference between the data as recorded by NEETRAC's RPM and the corresponding utility's RPM is also shown in Table B.

Table B. Benchmarking

	Utility B		Utility E		Utility C	
	Utility B RPM	NEETRAC RPM	Utility E RPM	NEETRAC RPM	Utility C RPM	NEETRAC RPM
Current THD (%)	18.2	17.6	10.6	10.3	14.0	14.7
Voltage THD (%)	2.14	2.20	1.03	0.98	1.87	1.96
% diff. in voltage THD of benchmarking data	-2.7		+4.9		-4.5	

Residential Field Sites

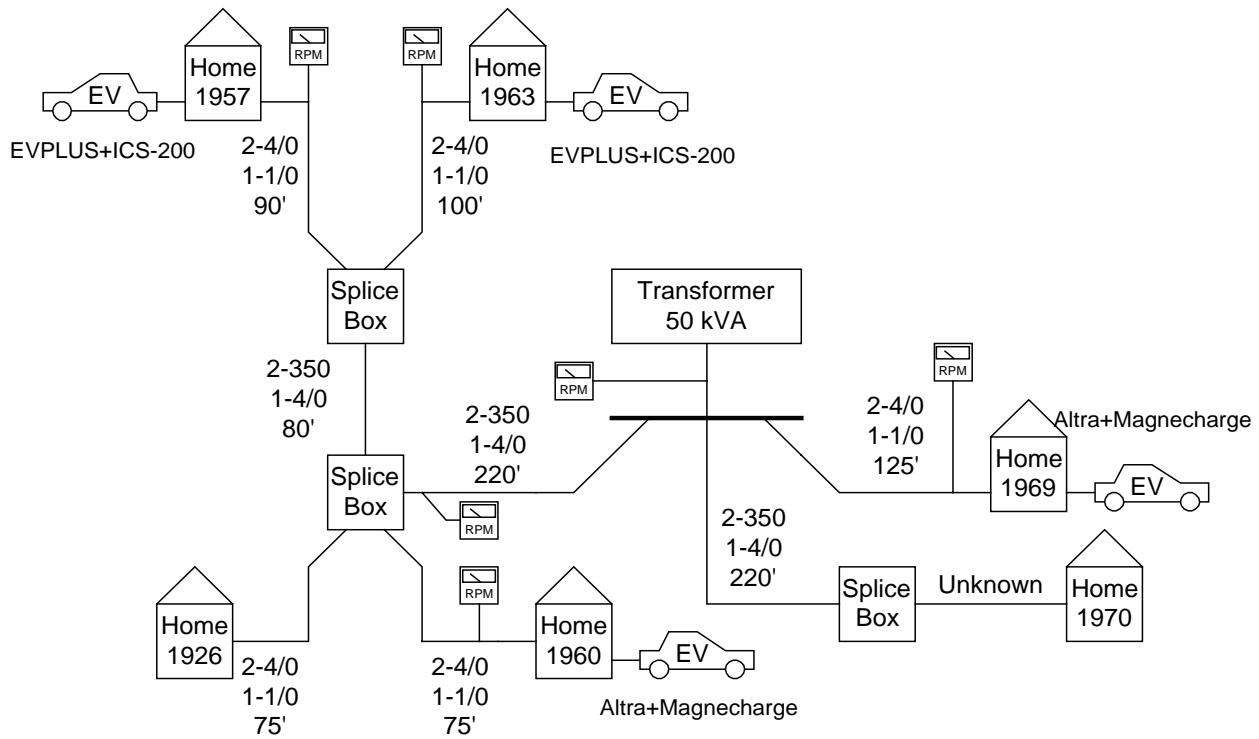
Utility B

The field site configuration of the system is shown in Figure 1. The field site consisted of six customers with four EVs among them. The field test site was chosen based on the proximity of the neighborhood to early EV adopters, the willingness of a utility employee and her neighbors to participate in the project, and the ability of the distribution system and the homes to physically and electrically handle EVs and chargers. The EVs used in the field site were Honda EVPLUSS and Nissan Altras. The chargers used in the testing process were the EVI ICS-200 for the EVPLUSS and Magnecharge models for the Altras.

Data were recorded by RPMs from 8/24/1999 to 9/20/1999. The various parameters of the field site configuration are shown in Table C. Monitoring equipment was placed at the houses with the EVs, a splice box and at the transformer secondary (see Figure 1). The chargers except at Home #1957 were programmed to start charging at midnight to ensure overloading of the transformer did not occur. Utility B used time clocks set to allow charging at midnight because it has a mandatory rate schedule for electric vehicle chargers that is based on time of use charges. Utility B has found that most EV customers use timers to initiate charging at midnight to minimize their EV charging costs. Since the RPMs were located at the service to the house, the EVs cannot be distinguished from the other loads in the home. Hence an analysis of the non-linear characteristics of the EV cannot be performed. The data recorded over a typical 24-hour cycle when three chargers came on at midnight are shown in Figure 2.

Table C. Field Site System Parameters

Parameter	Value
EV Charger Penetration %	67 %
Distribution Service Transformer	50 kVA %Z=2.2 %R=1.5, %X=1.7
Secondary Conductor Used	350 Al
Service Conductor Used	4/0 Al
Average Length of conductor	100 ft.
No. of customers	6
Type of customer	Residential

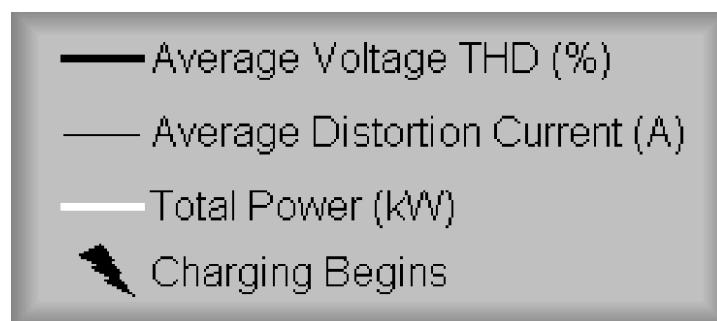


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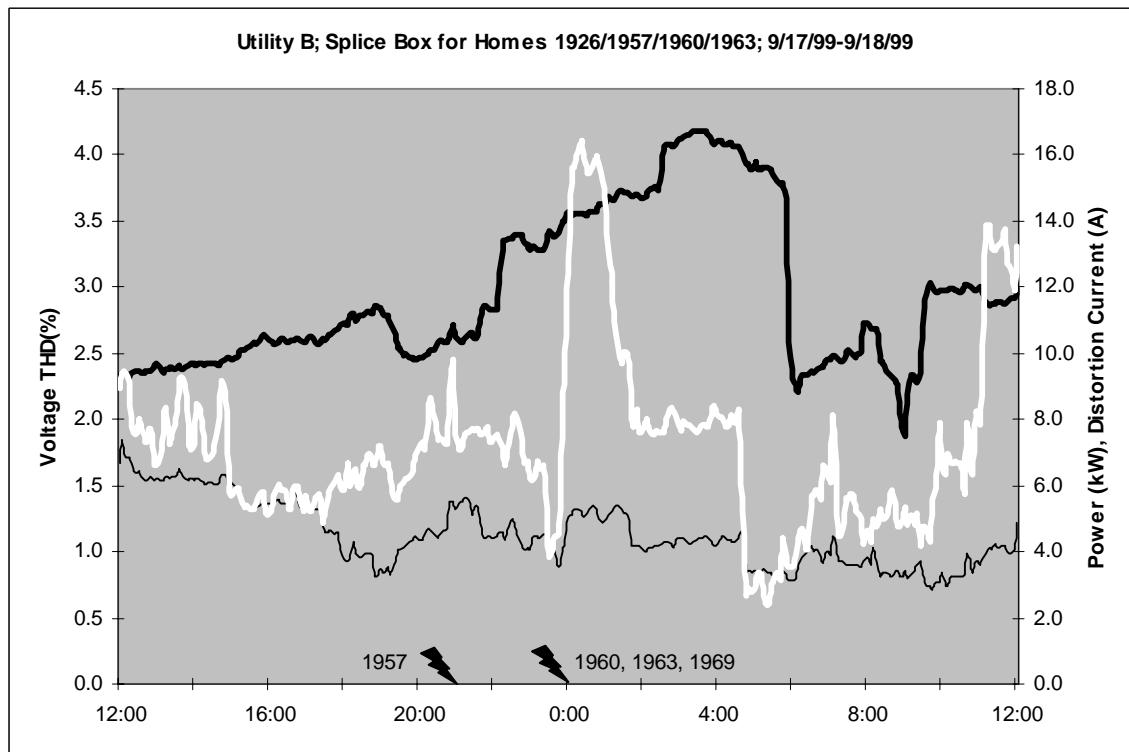
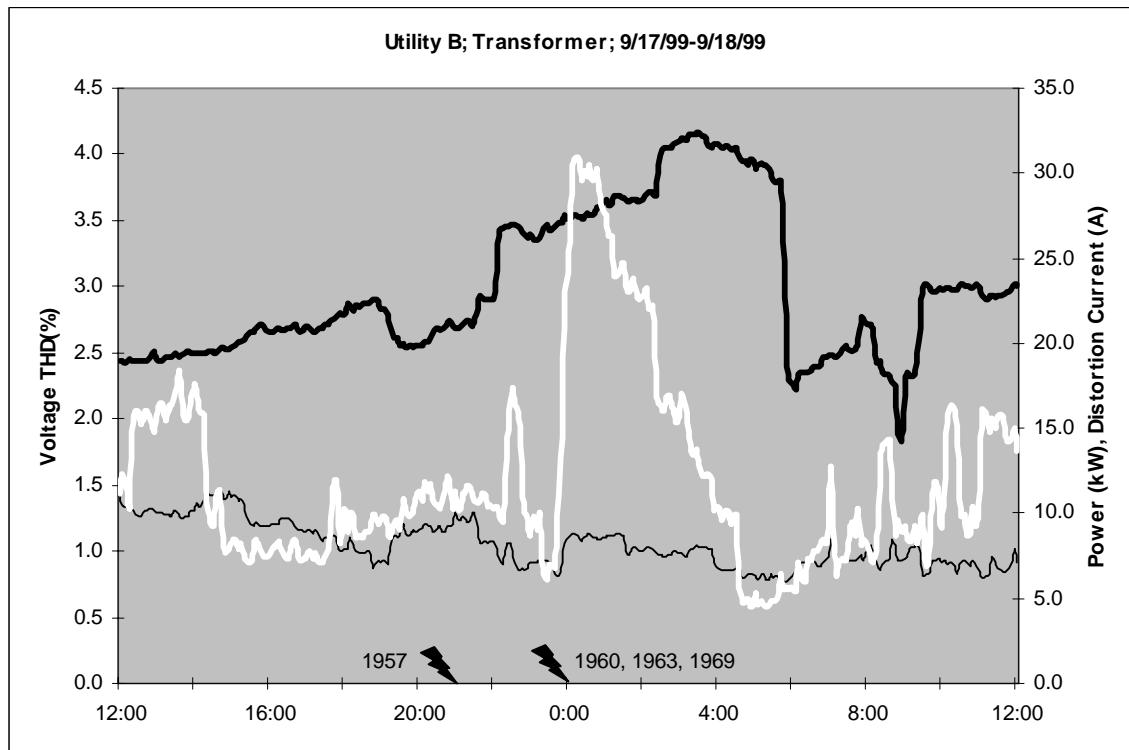
All conductors are aluminum.

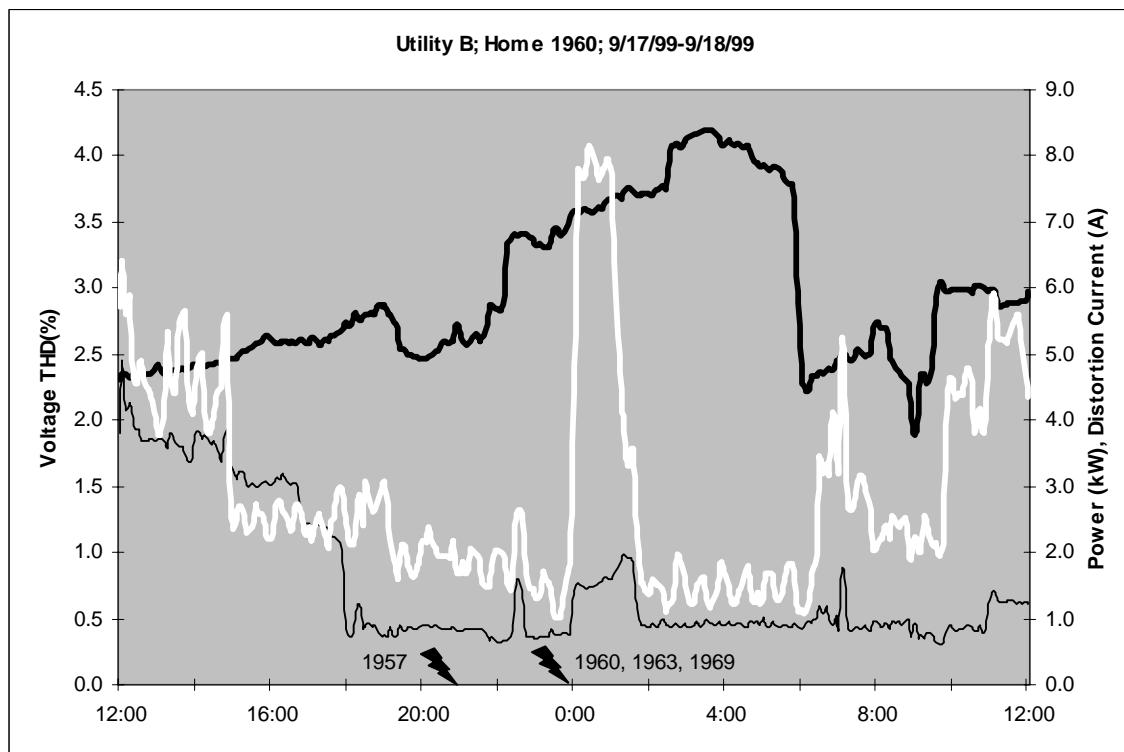
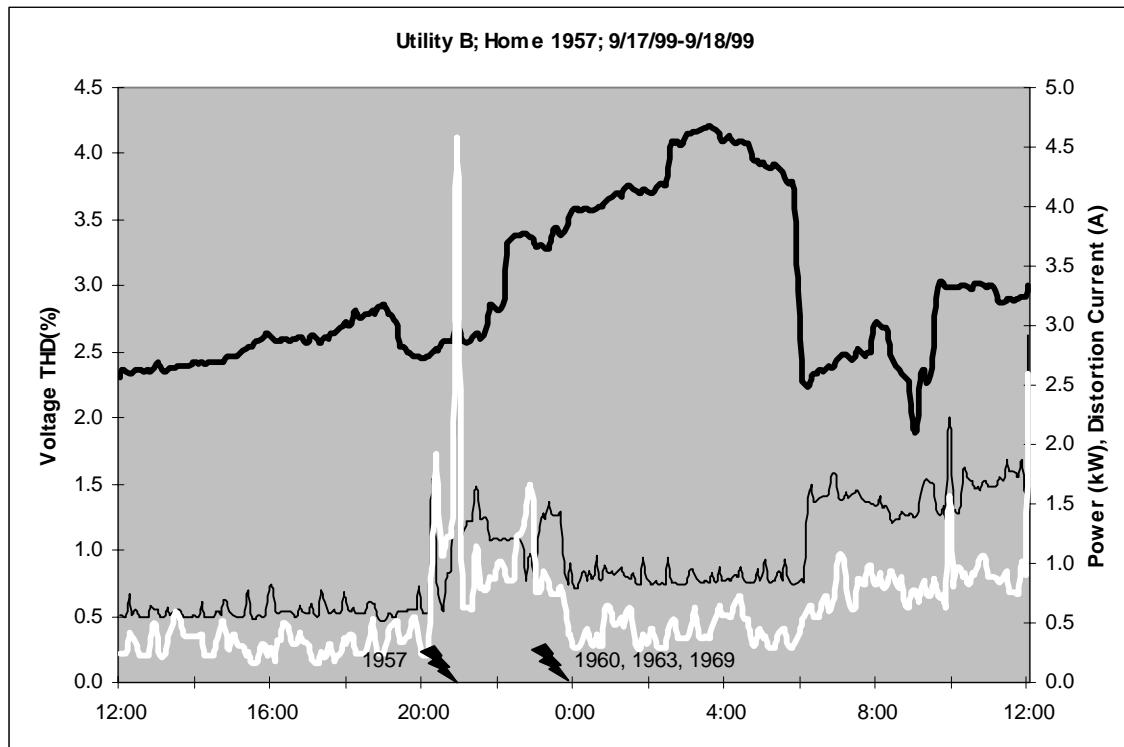
Figure 1. Utility B Test Site

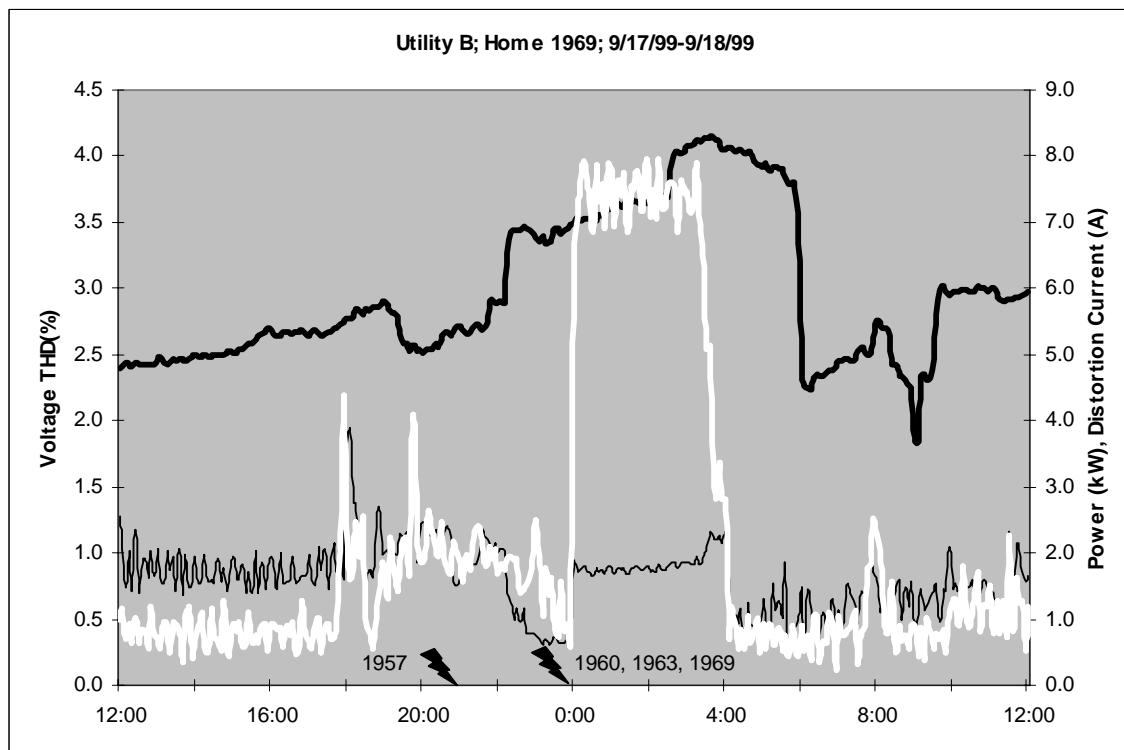
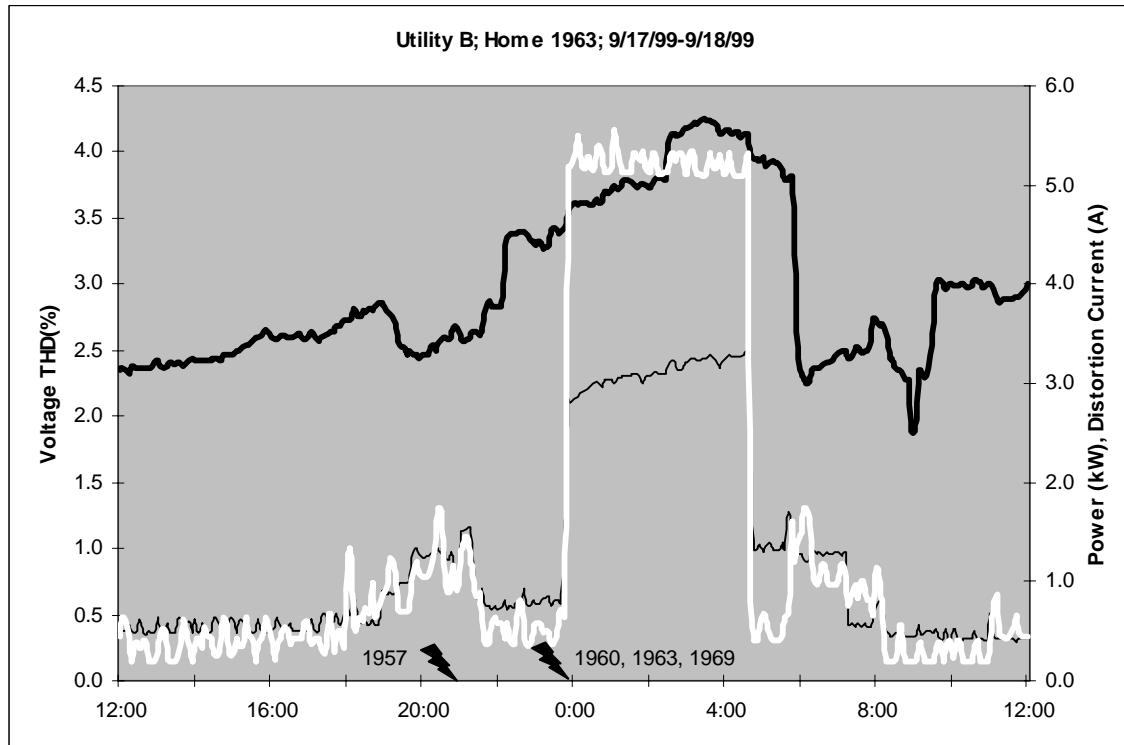
Figure 2. Utility B Test Site Data over a 24-hour cycle



Legend for distortion related graphs
(Graph Scales are different for clarity)







It can be seen from the graphs that the increase in voltage THD due to EV charging is less than 0.8% (see Appendix D.1, pg. 24). Rather, the system shows an increase in voltage THD, regardless

of the operation of the charger during nighttime (see Appendix D.1, pg. 4). This is a system phenomenon, which is most likely caused by other non-linear loads on the feeder or an adjacent feeder connected to the same distribution substation transformer.

- **Utility E**

The field site configuration of the system is shown in Figure 3. The field site consisted of thirteen customers with one EV (Ford Ranger) among them. The EVI-ICS-200 charger was used for charging the EV. The various parameters of the field site configuration are shown in Table D. Monitoring equipment was placed at the house with the EV, a neighboring house, at the charger itself and at the transformer secondary (see Figure 3). Data were recorded by RPMs from 8/12/1999 to 9/13/1999. The data recorded over a typical 24-hour cycle are shown in Figure 4.

Table D. Field Site System Parameters

Parameter	Value
EV Charger Penetration %	8 %
Distribution Service Transformer	50 kVA %Z=1.8
Secondary Conductor Used	350 Al
Service Conductor Used	#2 Al
Average Length of conductor	55 ft.
No. of customers	16
Type of customer	Residential

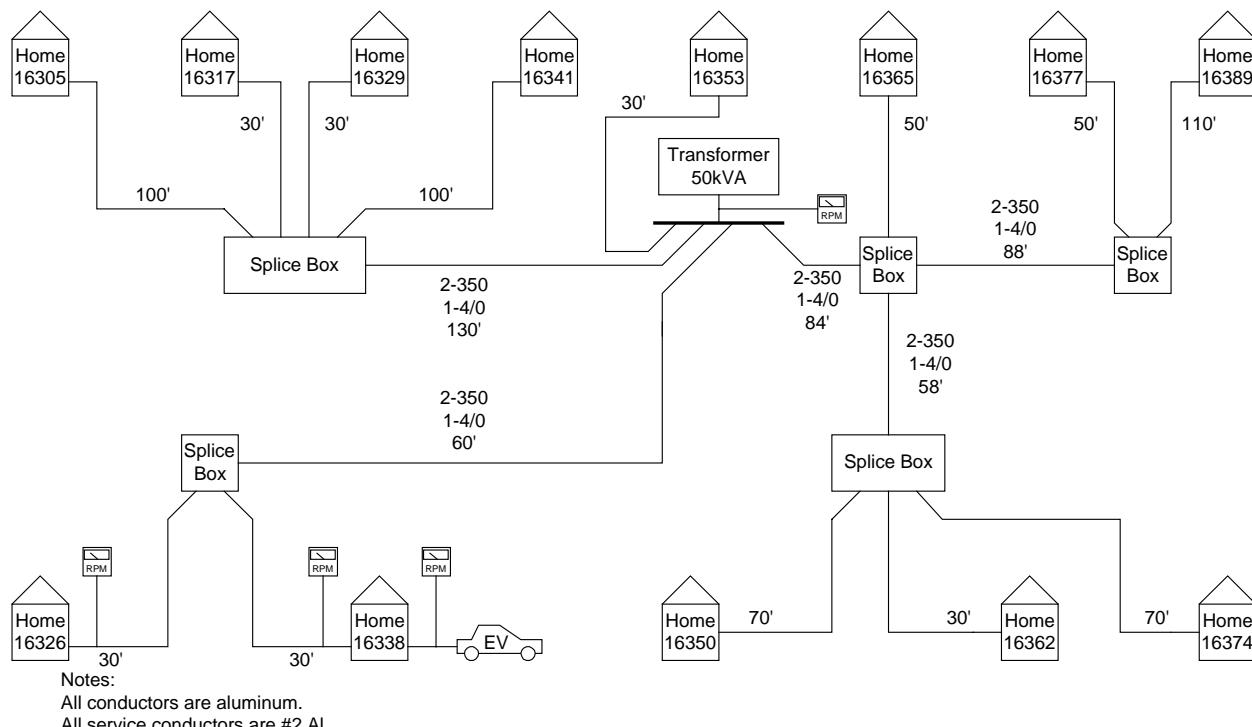
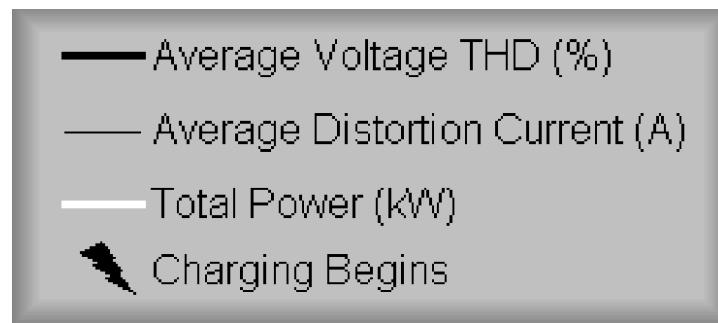
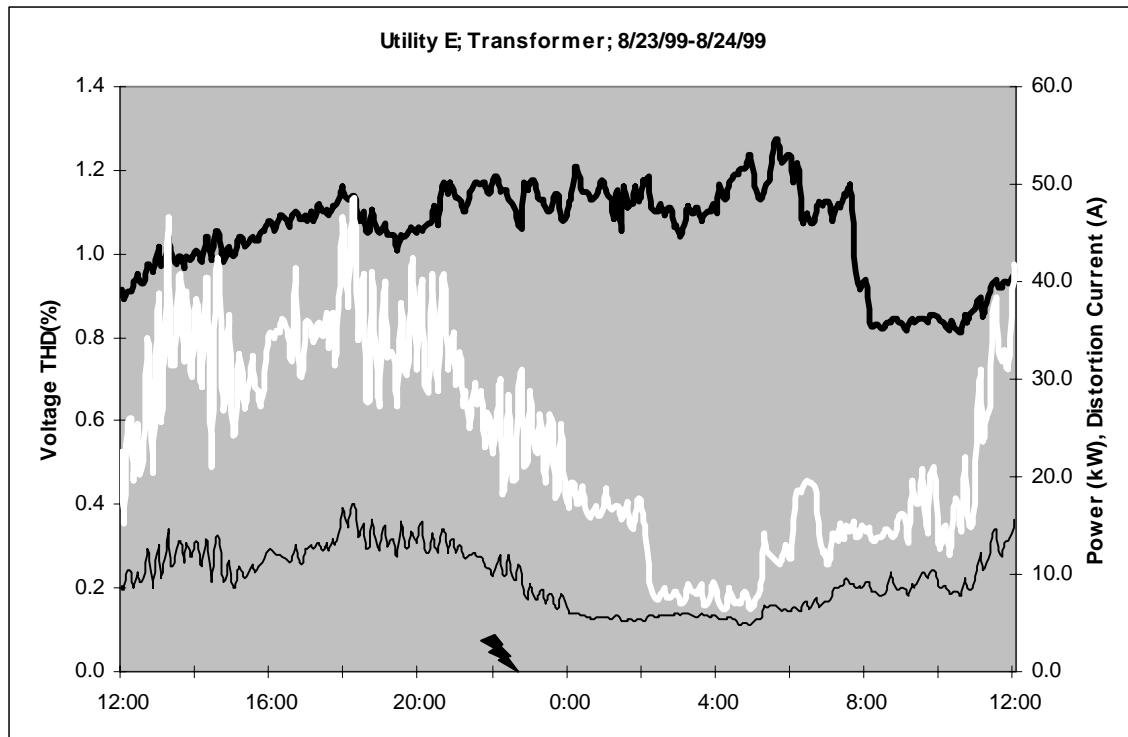


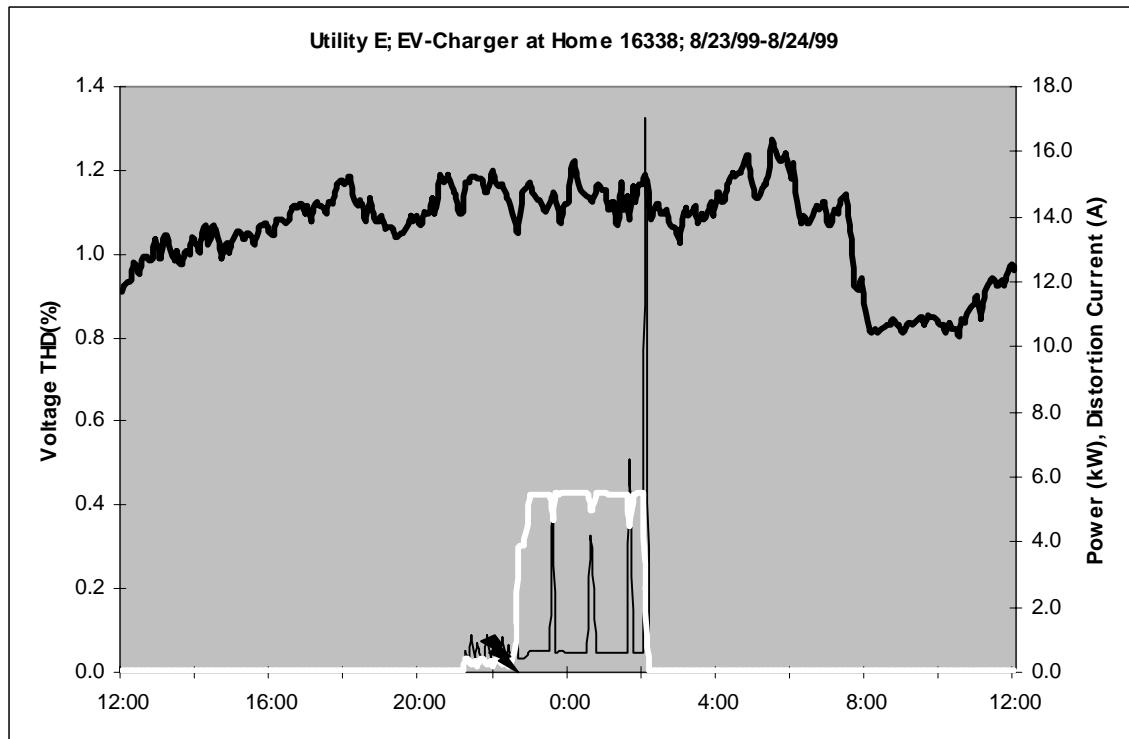
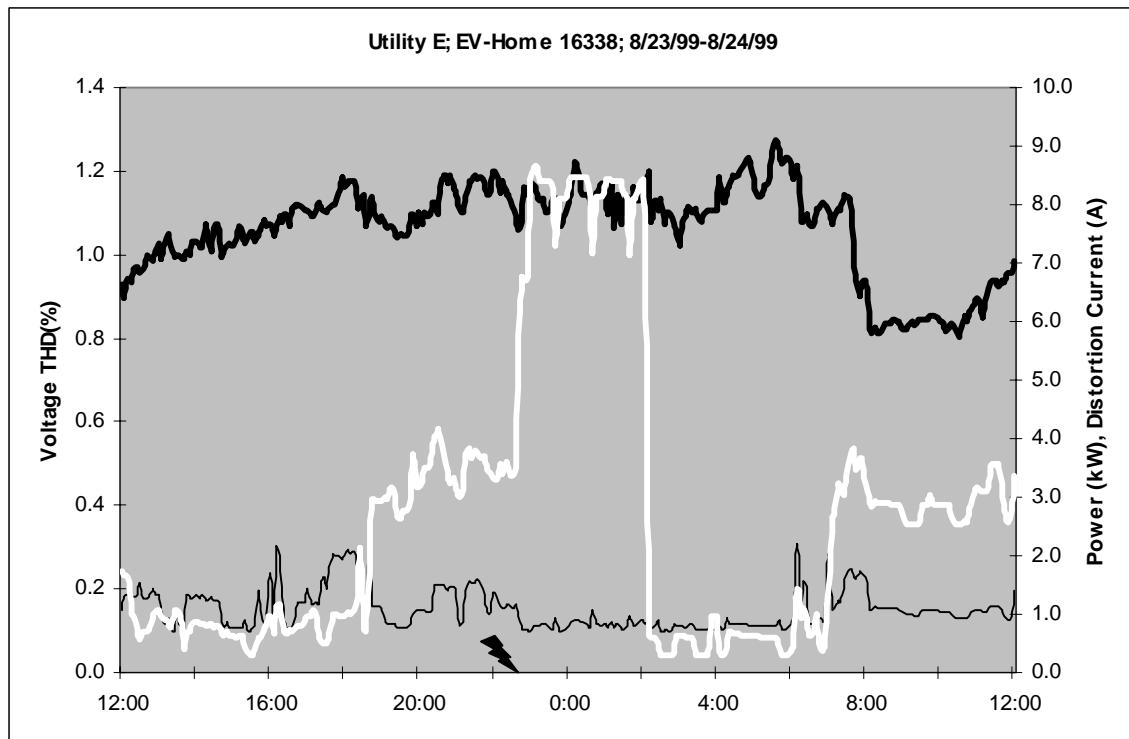
Figure 3. Utility E Test Site

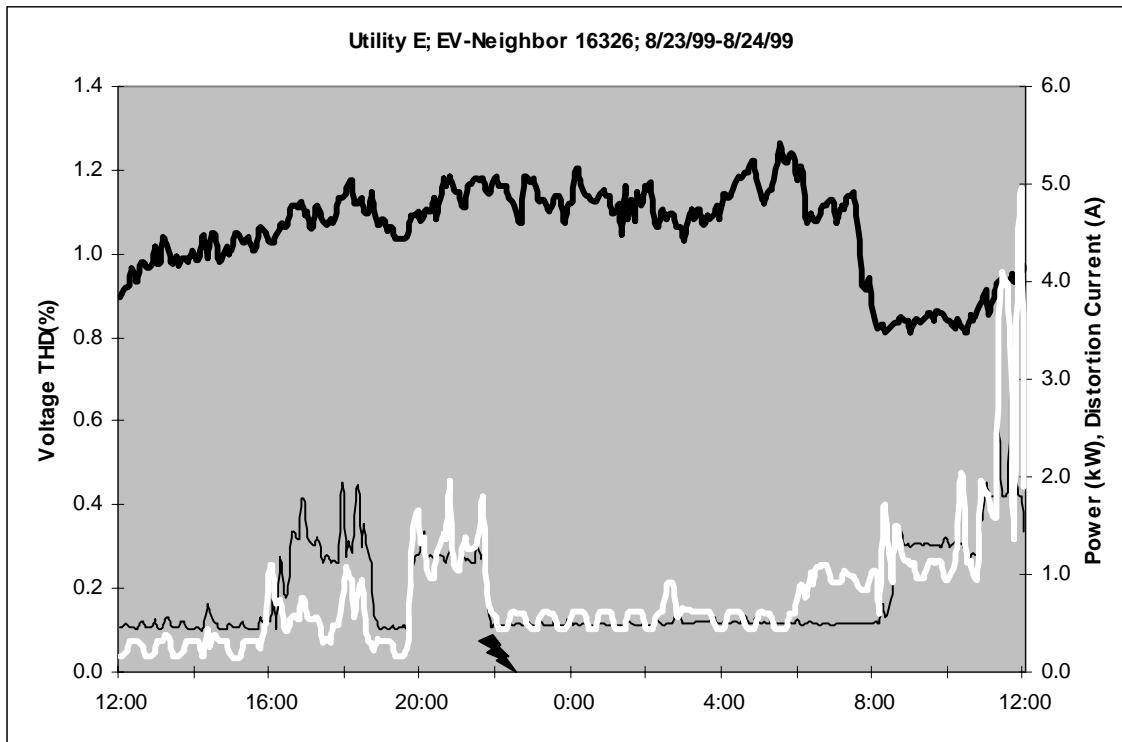
Figure 4. Utility E Test Site Data Over A 24-Hour Cycle



Legend For Distortion Related Graphs
(Graph Scales are different for clarity)







As can be seen from the typical graphs, there was no noticeable effect on the voltage distortion due to EV charging. Rather, the voltage THD seems to be a system effect as in Utility B's case.

Commercial Sites

- **Utility C**

Utility C chose a commercial parking deck used for EV fleet charging for its test site. The field site is a parking garage with a street level office complex. The same distribution transformer and service entrance serve the office complex and the EV charging station. The field site configuration is shown in Figure 5. Five EVs (Chrysler Epic, Honda EVPlus, Ford Ranger, General Motors EV1 and Chevrolet S-10) were used for the field tests. The Magnecharge charger was used for charging the EV1 and S-10 while the EVI ICS-200 was used to charge the Ranger and EVPlus. The Lockheed-Martin charger (three phase, 208 volts) was used for the Epic.

Monitoring equipment was placed at the EV charging sub-panel, office sub-panel and the main service entrance. Data were recorded by RPMs from 10/19/1999 to 11/1/1999. Data recorded over a typical 24-hour cycle are shown in Figure 6. Multiple EV charging took place in this site. A maximum of four EV chargers were charged at once at this site based on an EV charging demand of 25kW (see Appendix D.3, pg. 6). Qualitative assessments of whether any combinations of EVs led to worse conditions could not be made because the monitoring equipment was placed at the EV charging sub-panel and not at individual EVs. The symbols on the charts shown in Figure 6 and in Appendix D.3 indicate only the start of charging for the day.

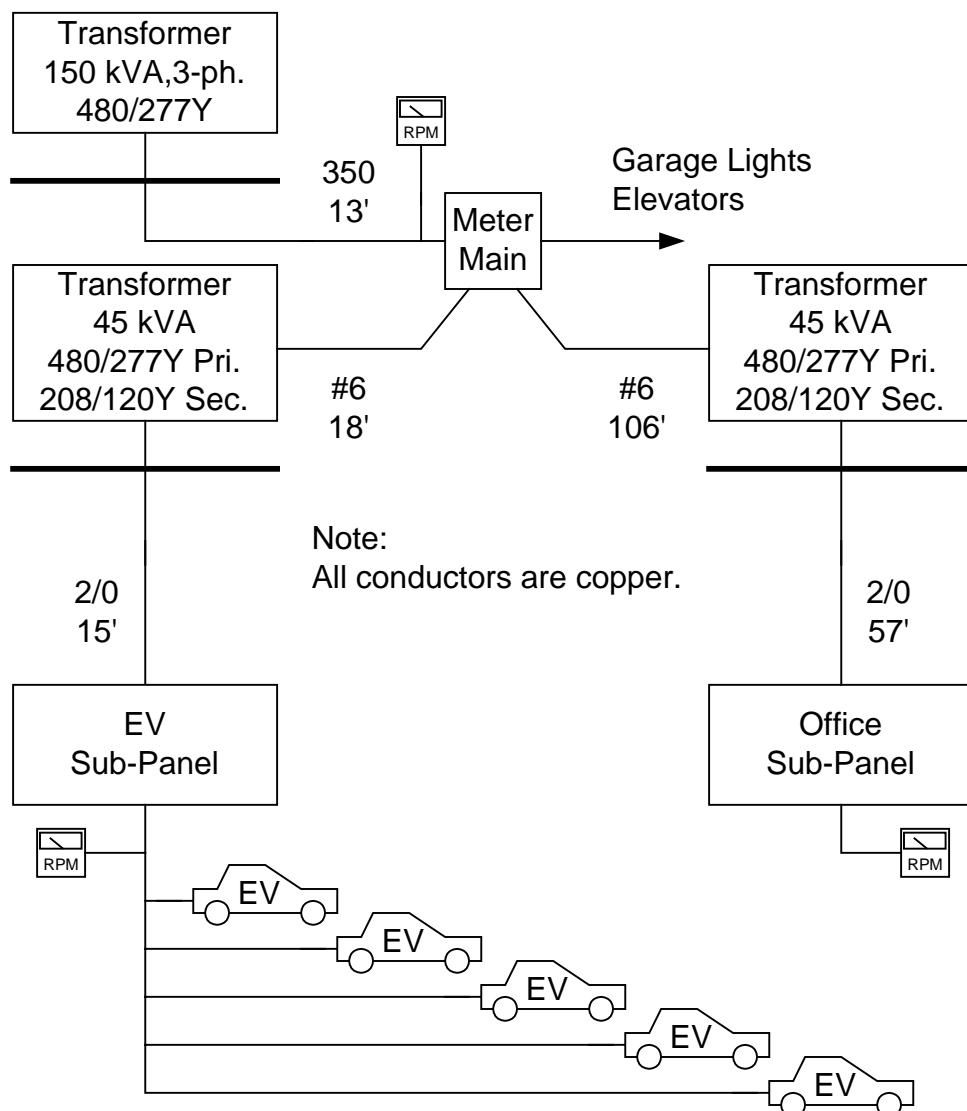


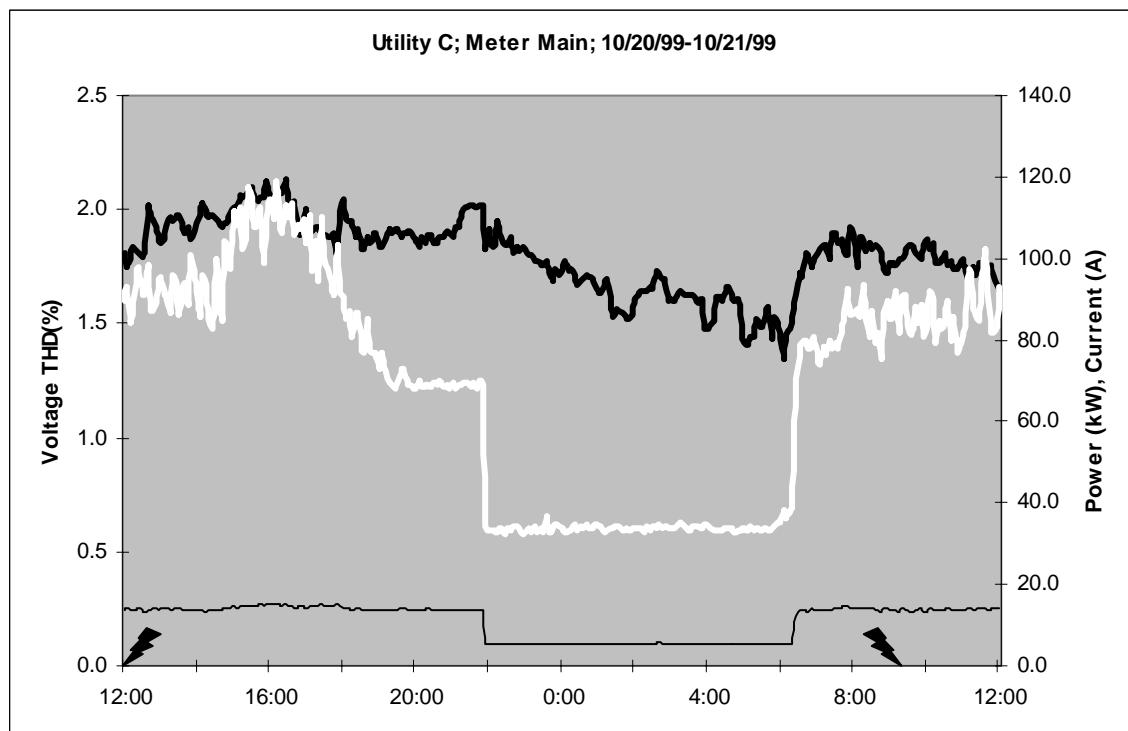
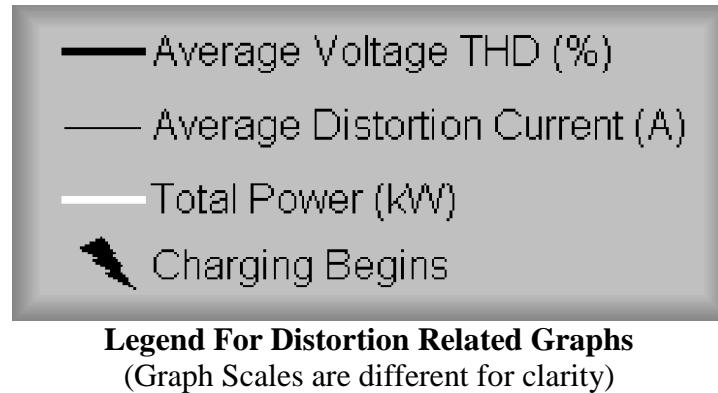
Figure 5. Utility C Test Site

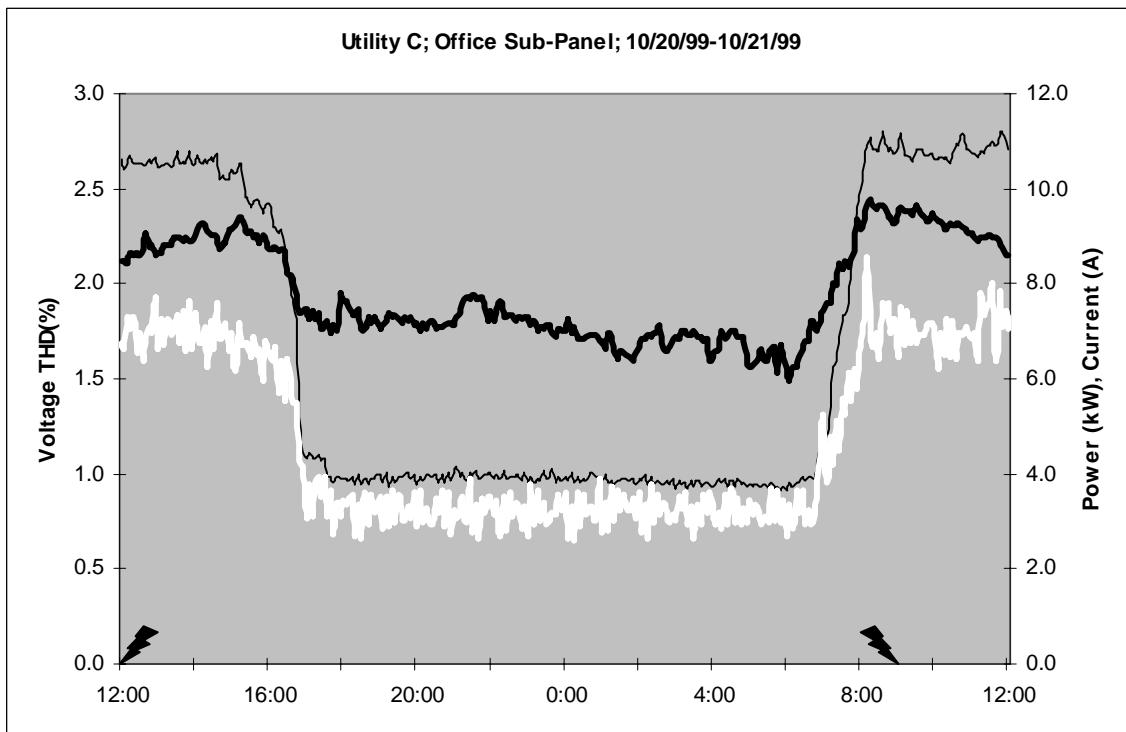
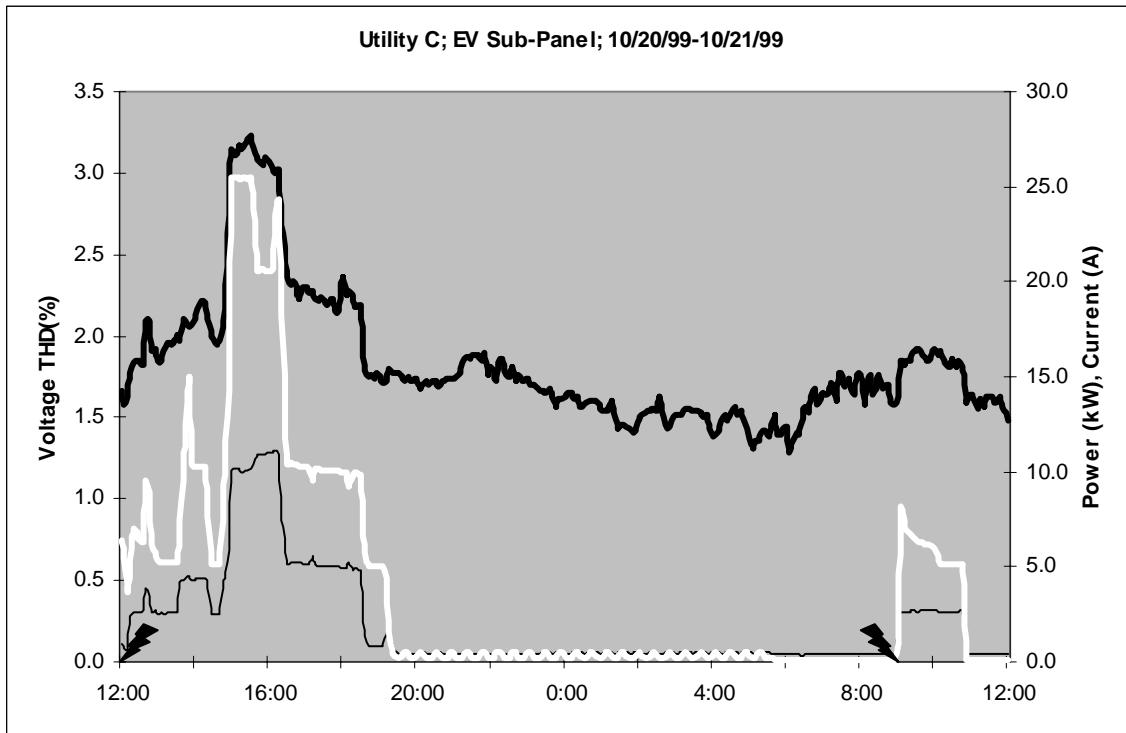
Table E. Field Site System Parameters

Parameter	Value
EV Charger Penetration %	N/A*
Distribution Service Transformer	150 kVA %Z =2.3
Secondary Conductor Used	350 Cu
Service Conductor Used	2/0 Cu
Average Length of conductor	15 ft.
No. of customers	N/A*
Type of customer	Commercial

- Utility C test site was a parking garage with commercial office space.

Figure 6. Utility C Test Site Data Over A 24-Hour Cycle





The effect of EV charging on voltage distortion at the transformer secondary is insignificant as is evident from the graphs. Though there is a rise in voltage distortion of 1.4% at the EV sub-panel, the main entrance does not show significant rise (less than 0.1%) in voltage THD. This could be attributed to the impedance of the wye-wye connected step down transformer and some phase cancellation of the harmonics.

It can also be seen that the voltage distortion at the office sub-panel and the EV sub-panel follows the pattern of the corresponding loads. A plot of the voltage distortion at the transformer secondary, office sub-panel, and EV sub-panel is shown in Figure 7 to illustrate the independence of the voltage distortion at the transformer secondary.

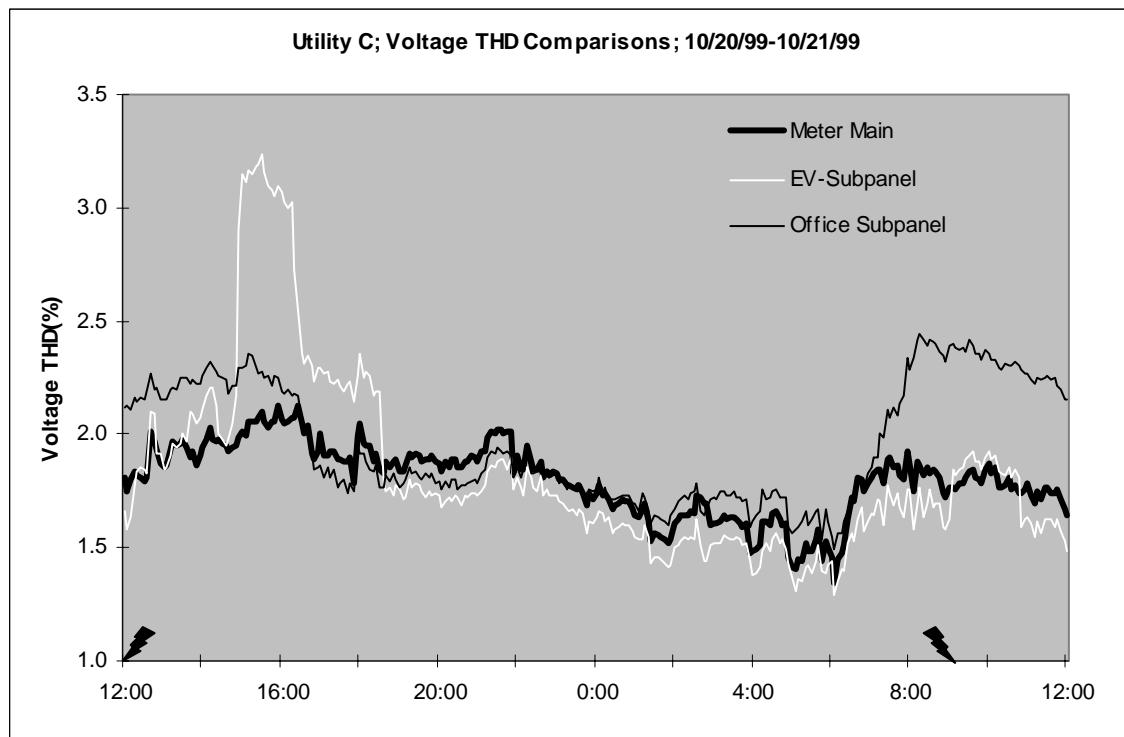


Figure 7. Voltage THD Comparison

Comparative Study

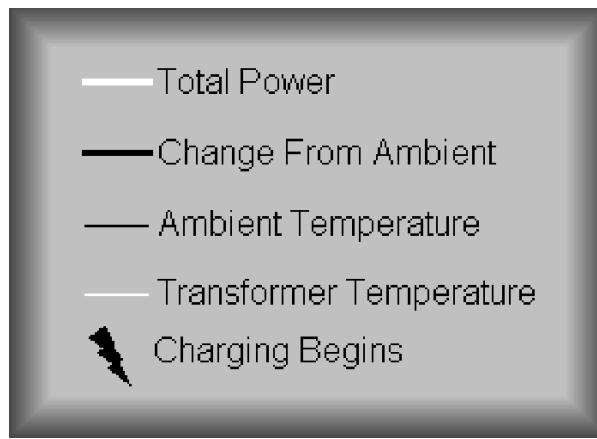
Utility B field test site was modeled and simulated following the methodology described in the earlier phases of the project. The appliances simulated were based on the field test appliances but do not exactly match them. Detailed results and simulation details are given in Appendix D.4. A comparison of the simulation results obtained and the field data is presented in Table F. It can be seen from Table F that the simulation results of the voltage THD closely match the field data to within 2.9%. This serves to validate the modeling and simulation process developed during the course of this project.

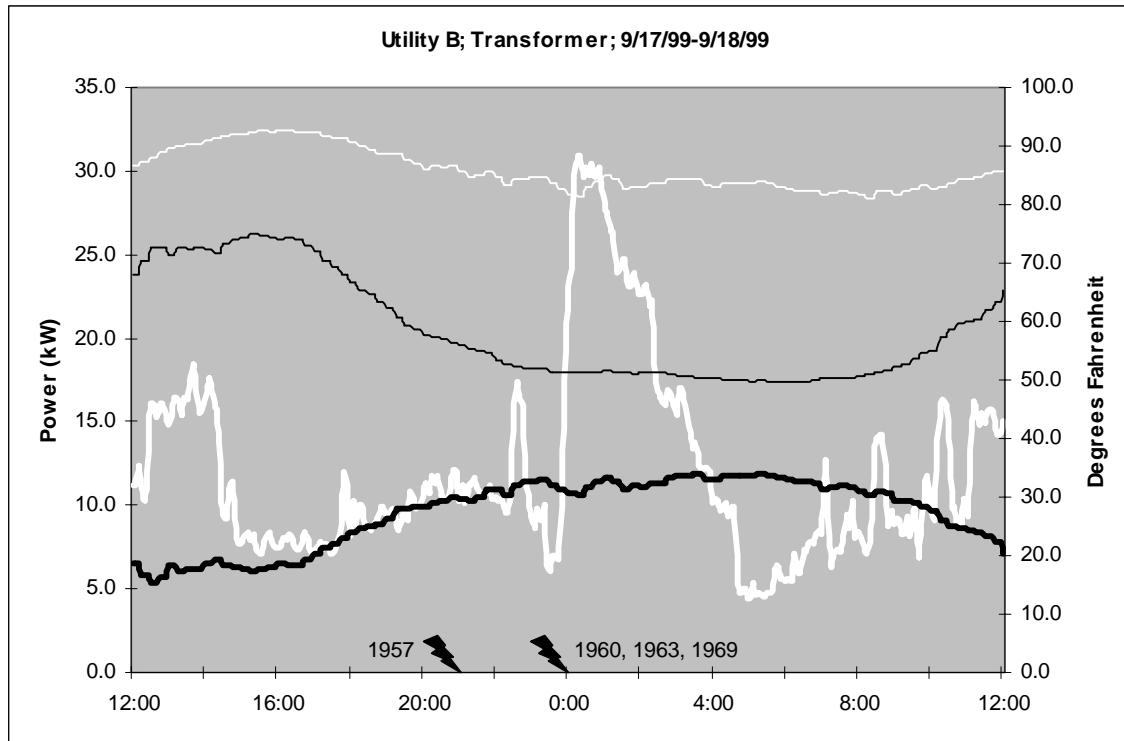
Table F. Comparison of Simulation Results and Field Data

	Before Charging			During Charging		
	Simulation	Field Data	% Diff.	Simulation	Field Data	% Diff.
X1 Line Current	26.2 A 21.1% THD	24.4 A 23.4% THD	7.4 -9.8	117.9 A 7.6% THD	123.8A 7.2% THD	-4.8 5.6
X3 Line Current	30.8 A 30.8% THD	31.3 A 24.1% THD	-1.6 27.8	122.7 A 7.3% THD	127.3 A 7.1 % THD	-3.6 2.8
Secondary Voltage	119.8 V 3.5% THD	123.8 V 3.4% THD	-3.2 2.9	118.9 V 3.6% THD	123.1 V 3.5% THD	-3.4 2.9
Line Losses	8.3 W	10.1 W	-17.8	16.6 W	18.2 W	-8.8
Transformer Losses	140.4 W	146.2 W	-4.0	252.1 W	288.2 W	-12.5
K Factor	1.5	1.6	-6.3	1.1	1.1	0.0
Transformer De-rating	0.98	0.98	0.0	1.0	1.0	0.0

Transformer Temperature Analysis

Transformer temperature data were also recorded in the Utility B test site. The correlation of voltage THD to the rise in temperature, if any, was investigated with the data recorded. The recorded temperature data have been presented in entirety in Appendix D.5. A sample graph of the variation of the transformer temperature over one day is shown in Figure 8. The field test showed that the rise in voltage THD does not influence the heating of the transformer. The change in transformer temperature from ambient tracks the loading of the transformer with a time lag due to the thermal capacitance of the transformer.

Figure 8. 24 Hour Temperature Graph



Field Data Summary

A summary of the recorded data is provided below to identify the worst case conditions for the particular system configuration. The maximum observed values for the system conditions in the recorded data were determined. These could serve as important information for the utilities in identifying overloads and high background distortion levels for the field test site in particular and other similar feeders. The maximum observed values for the system conditions are shown in Table G.

Table G. Maximum Observed Values at Transformer Secondary

Maximums	Utility B		Utility E		Utility C	
	Without EV Charging	With EV Charging	Without EV Charging	With EV Charging	Without EV charging	With EV charging
Voltage THD (%)	4.0 (6:59 AM)	4.1 (2:54 AM)	1.4 (7:30 AM)	1.3 (0:40 AM)	2.3 (3:40 PM)	2.4 (5:10 PM)
Distortion Current (A)	15.1 (11:12 PM)	10.9 (0:20 AM)	17.3 (6:15 PM)	14.7 (11:50 PM)	15.0 (2:40 PM)	15.5 (4:00 PM)
Transformer Loading (%)	84 (8:45 PM)	65 (0:15 AM)	117 (9:30 PM)	77 (9:30 PM)	63 (1:05 PM)	80 (4:25 PM)

Note: The time of observation of each maximum has been provided within brackets.

The low percentage loading and voltage distortion with EV charging are probably due to the chargers coming on at nighttime when the loading is minimal. An assessment of the total loading of the transformer if EVs were charged during peak hours instead of at off-peak hours is made in Table H. It can be noticed that for Utilities B and E the system is overloaded with peak hour EV charging. Since Utility C was a commercial test site, charging was done during peak hours and it can be seen that the assessment matches the field data (See columns for Utility C in Tables G and H). Load management strategies like off peak charging should be encouraged to minimize impacts on the distribution system.

Table H. Impact of Peak Hour EV Charging on Overloading

Maximums	Utility B	Utility E	Utility C
EV loading (%)	36	11	16
No. of EVs charging simultaneously	3	1	4
Transformer Loading with Peak charging (%)	120	128	79

Conclusions

- Field site studies were performed by three utilities.
- Selected data from the field test sites are shown in the appendices.
- The field site data confirm the results reported in the Third Interim Report, that commercial EV chargers engineered to IWC guidelines do not give rise to excessive voltage THD on the secondary of the transformer. Two critical elements that make these guidelines effective are a minimum total power factor of 95% and a maximum current THD of $\leq 20\%$.
- The rise in voltage THD due to EV charging was found to be within 0.8% in all the three field test sites and should not be a cause for concern. Load management strategies like off peak charging should be encouraged to minimize load impacts on the distribution system.
- Simulation studies of one of the test sites were performed and the field data and the simulation results of the voltage THD were found to match within 2.9%, validating the modeling and simulation process developed during the course of this project.
- An evaluation of worst-case service configurations has been performed. These data are likely to be useful for utility planners in estimating overloads and analyzing other system phenomena for the corresponding feeder.
- The influence of EV charging on transformer temperature at one field site was studied. Temperature rise was not attributable to voltage THD but was affected rather by the extra loading on the transformer due to the EVs.
- The main cause of concern is the overloading of the distribution transformer with widespread use of EV chargers, assuming the chargers meet voluntary IWC guidelines such that voltage THD is not an issue. Still, utility service planning groups should ask for kVA and true power factor values in addition to kW values for any rectifier or other non-linear load.



Appendix A.1

Instrument Comparison



Comparison of Fluke41B and BMI3030

<u>Equipment</u>	<u>% of Normal Volt.</u>	<u>Electrical Qty</u>	<u>Fluke</u>	<u>BMI</u>	<u>% BMI differs from Fluke90</u>
Dryer	100	Frequency	59.98	60	0.033344
		RMS Voltage	236.9	240	1.308569
		RMS Current	20.3	20.7	1.970443
		KW	4.81	5.194	7.983368
		Voltage Crest Factor	1.41	1.4	-0.70922
		Current Crest Current	1.41	1.4	0.70922
		THD Fund Voltage	2	2	0
		THD Fund Current	2.04	2.6	27.45098
		DPF	1	1	0
Dryer	90	Frequency	59.98	60	0.033344
		RMS Voltage	216.5	216	-0.23095
		RMS Current	18.58	18.6	0.107643
		KW	4.02	4.22	4.975124
		Voltage Crest Factor	1.41	1.4	-0.70922
		Current Crest Factor	1.4	1.4	0
		THD Fund Voltage	1.91	1.9	-0.52356
		THD Fund Current	2.01	2.4	19.4029
		DPF	1	1	0
Oven	100	Frequency	59.98	60	0.033344
		RMS Voltage	235	240.5	2.340426
		RMS Current	24.75	26	5.050505
		KW	5.81	6.196	6.643718
		Voltage Crest Factor	1.41	1.4	-0.70922
		Current Crest Factor	1.41	1.5	6.382979
		THD Fund Voltage	1.94	2	3.092784
		THD Fund Current	1.78	2.2	23.59551
		DPF	1	1	0
Oven	90	Frequency	59.98	60	0.033344
		RMS Voltage	217.2	215.5	-0.78269
		RMS Current	23.64	23.3	-1.43824
		KW	5.13	4.966	-3.19688
		Voltage Crest Factor	1.41	1.4	-0.70922
		Current Crest Factor	1.4	1.4	0
		THD Fund Voltage	1.97	1.9	-3.5533
		THD Fund Current	1.83	2.1	14.7541
		DPF	1	1	0
Washing Machine	100	Frequency	60.04	60	-0.06662
		RMS Voltage	121.33	No DATA	
		RMS Current	6.48	No DATA	
		KW	0.42	0.3796	-9.61905
		Voltage Crest Factor	1.41	No DATA	
		Current Crest Factor	1.41	No DATA	
		THD Fund Voltage	2.03	2	-1.47783
		THD Fund Current	5.24	5.7	8.778626
		DPF	0.53	No DATA	

Water Heater	100	Frequency	59.98	60	0.033344
		RMS Voltage	240.4	239.9	-0.20799
		RMS Current	18.01	17.9	-0.61077
		KW	4.33	4.328	-0.04619
		Voltage Crest Factor	1.41	1.4	-0.70922
		Current Crest Factor	1.4	1.5	7.142857
		THD Fund Voltage	1.94	1.9	-2.06186
		THD Fund Current	2.05	2.2	7.317073
		DPF	1	1	0
Water Heater	90	Frequency	59.98	60	0.033344
		RMS Voltage	216.6	216.1	-0.23084
		RMS Current	16.39	16.2	-1.15924
		KW	3.55	3.527	-0.64789
		Voltage Crest Factor	1.41	1.4	-0.70922
		Current Crest Factor	1.4	1.4	0
		THD Fund Voltage	1.94	1.9	-2.06186
		THD Fund Current	2.16	2.2	1.851852
		DPF	1	1	0



Appendix A.2

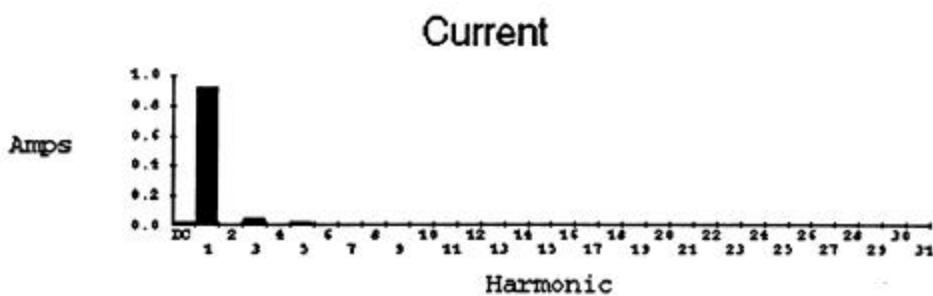
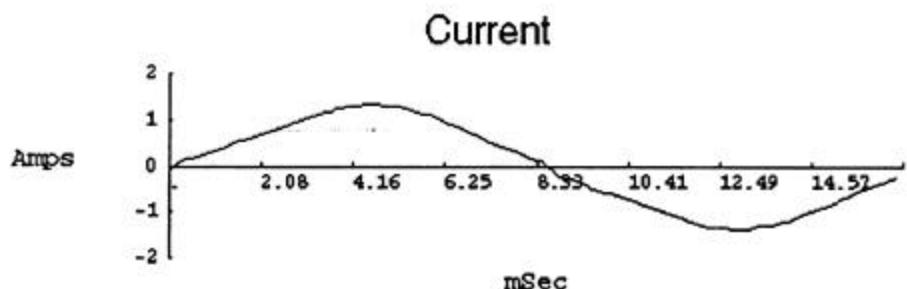
Kitchen Appliances



Mixer
Model - Moulinex Food Processor 130
Ratings - 120V,250W

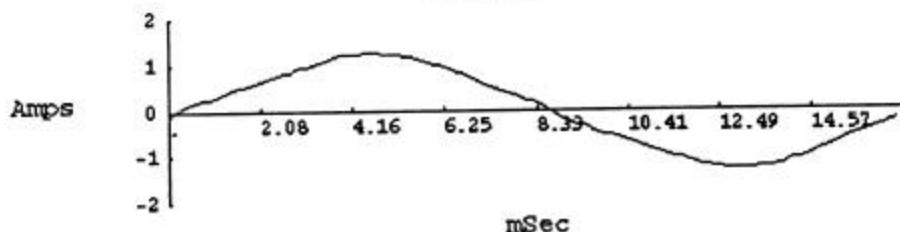
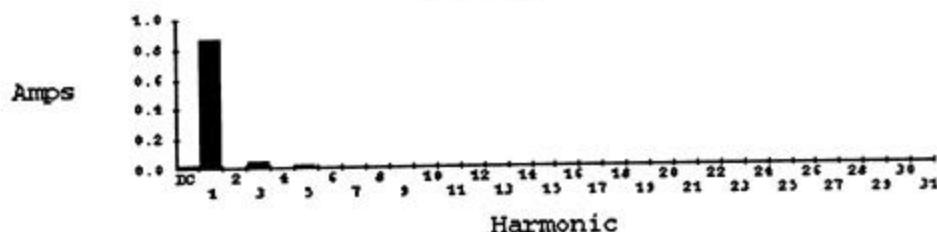
High Power Setting
Normal Voltage Condition

		Voltage	Current
Frequency	60.04	RMS	119.41
Power		Peak	168.73
Watts	109.29	DC Offset	-0.02
VA	110.33	Crest	1.41
Vars	12.13	THD Rms	1.84
Peak W	235.71	THD Fund	1.84
Phase	6° lag	HRMS	2.20
Total PF	0.99	KFactor	0.06
DPF	0.99		1.14



Mixer**Model - Moulinex Food Processor 130****Ratings - 120V, 250W****High Power Setting****Low Voltage Condition**

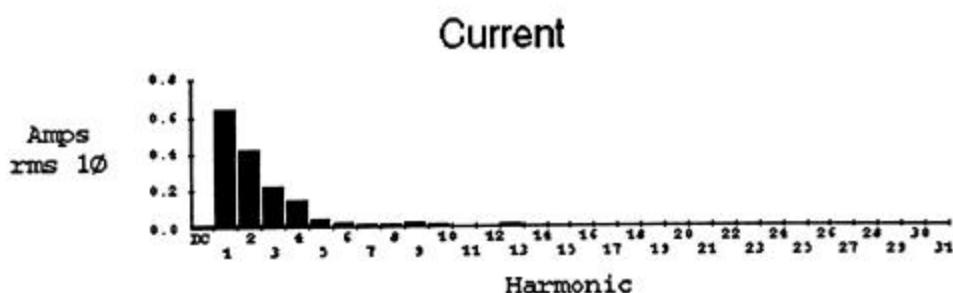
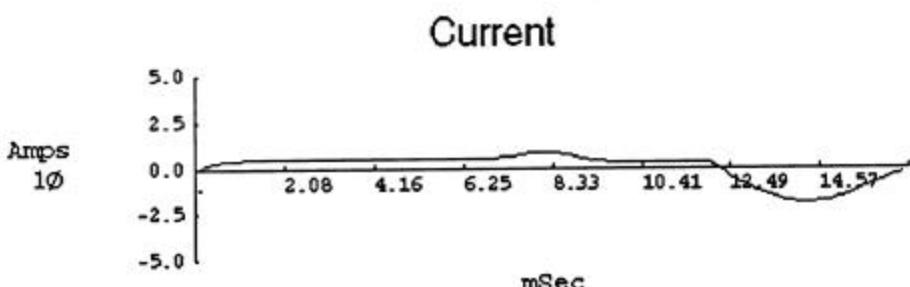
		Voltage	Current
Frequency	60.04	RMS	0.88
Power		Peak	1.32
Watts	93.29	DC Offset	-0.02
VA	94.33	Crest	1.51
Vars	12.13	THD Rms	6.16
Peak W	202.71	THD Fund	6.17
Phase	8° lag	HRMS	0.05
Total PF	0.99	Kfactor	1.13
DPF	0.99		

Current**Current**

Mixer**Model - Moulinex Food Processor 130****Ratings - 120V, 250W**

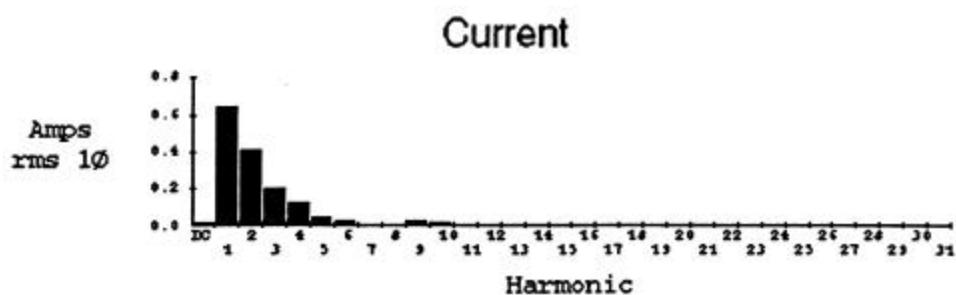
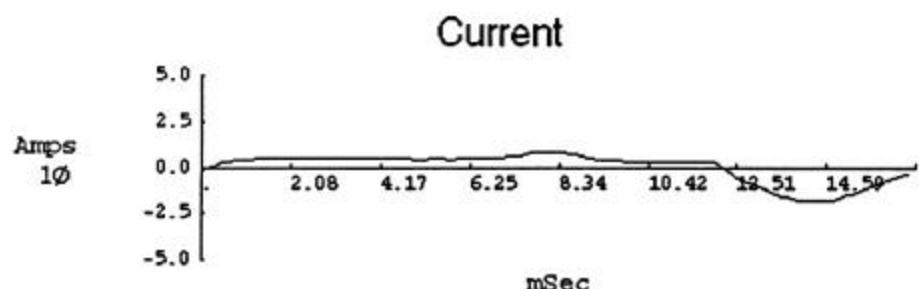
Low Power Setting
High Voltage Condition

		Voltage	Current
Frequency	60.04	RMS	119.81
Power		Peak	169.70
Watts	58.29	DC Offset	0.18
VA	97.33	Crest	1.42
Vars	50.13	THD Rms	1.90
Peak W	273.71	THD Fund	1.90
Phase	41° lag	HRMS	2.28
Total PF	0.60	KFactor	0.50
DPF	0.76		3.39



Mixer**Model - Moulinex Food Processor 130****Ratings - 120V, 250W****Low Power Setting****Low Voltage Condition**

		Voltage	Current
Frequency	59.98	RMS	108.14
Power		Peak	153.23
Watts	51.29	DC Offset	0.29
VA	85.33	Crest	1.42
Vars	46.13	THD Rms	1.83
Peak W	236.71	THD Fund	1.83
Phase	42° lag	HRMS	1.98
Total PF	0.60	Kfactor	0.48
DPF	0.74		3.23



Mixer

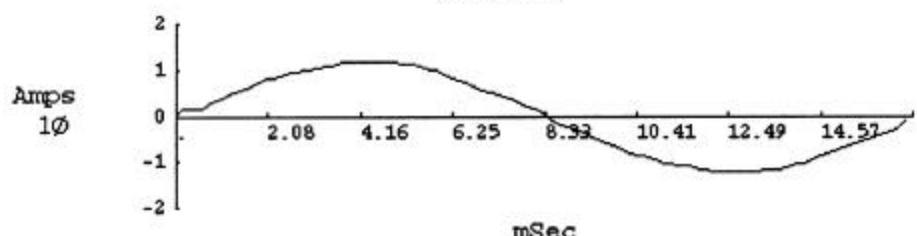
Model - Kitchen Aid KA5SS

Ratings - 115V, 250W (Yr - 1991)

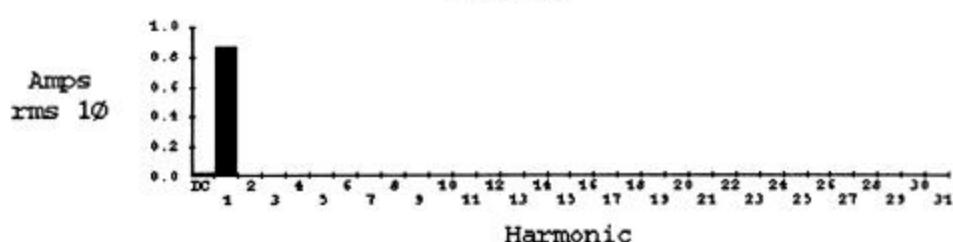
Normal Voltage Condition

		Voltage	Current
Frequency	60.04	RMS	120.05
Power		Peak	168.75
Watts	103.31	DC Offset	0.03
VA	103.41	Crest	1.41
Vars	3.16	THD Rms	2.05
Peak W	212.80	THD Fund	2.05
Phase	2° lag	HRMS	2.47
Total PF	1.00	KFactor	0.03
DPF	1.00		1.17

Current



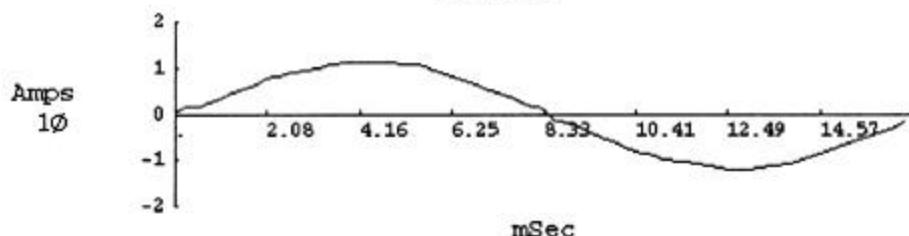
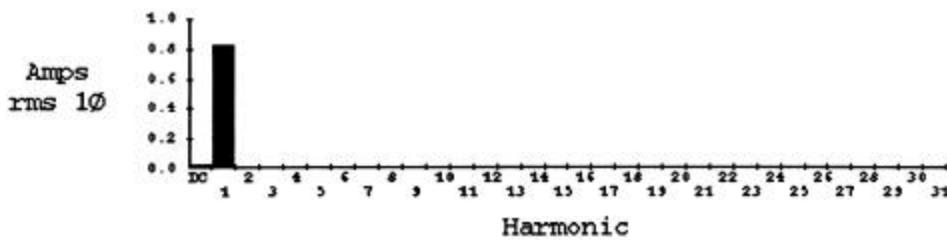
Current



Mixer**Model - Kitchen Aid KA5SS****Ratings - 115V, 250W (Yr - 1991)**

Low Voltage Condition

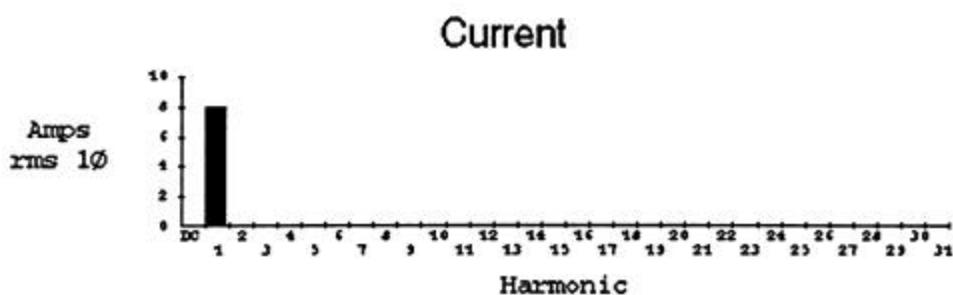
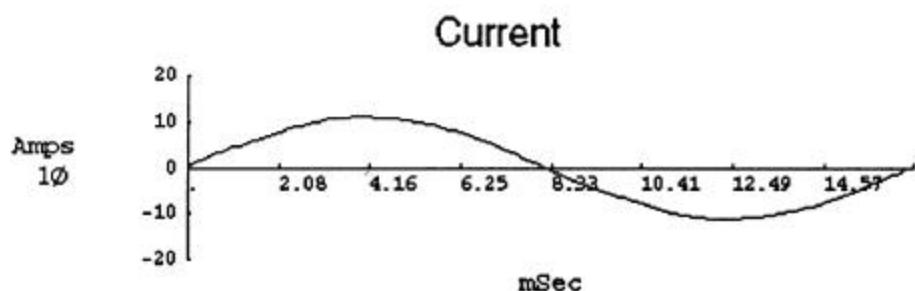
		Voltage	Current
Frequency	60.04	RMS	0.83
Power		Peak	1.19
Watts	90.31	DC Offset	-0.02
VA	90.41	Crest	1.42
Vars	4.16	THD Rms	3.37
Peak W	184.80	THD Fund	3.37
Phase	3° lag	HRMS	0.03
Total PF	1.00	KFactor	1.19
DPF	1.00		

Current**Current**

Coffee Maker
Model - Mr. Coffee PRX23
Ratings - 120V, 1025W

Heating mode
Normal Voltage Condition

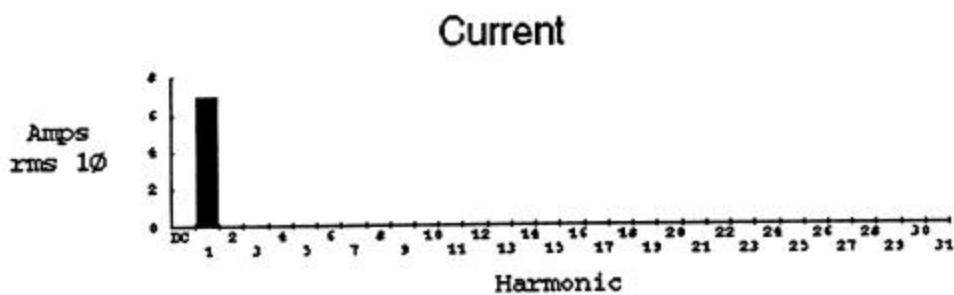
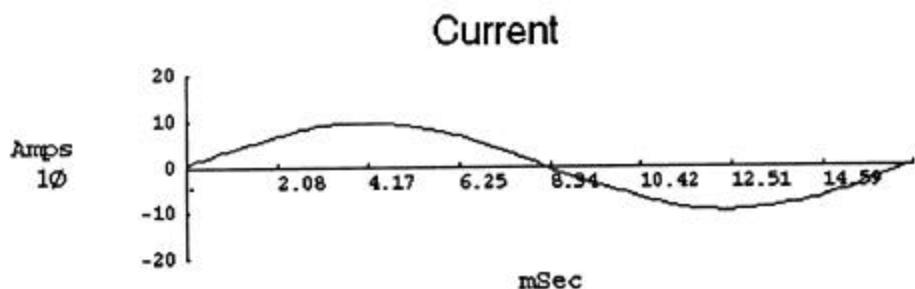
		Voltage	Current
Frequency	60.04	RMS	119.58
Power		Peak	169.44
KW	0.96	DC Offset	0.00
KVA	0.96	Crest	1.42
KVAR	0.03	THD Rms	1.90
Peak KW	1.92	THD Fund	1.90
Phase	2° lead	HRMS	2.27
Total PF	1.00	KFactor	1.01
DPF	1.00		



Coffee Maker
Model - Mr. Coffee PRX23
Ratings - 120V, 1025W

Heating mode
Low Voltage Condition

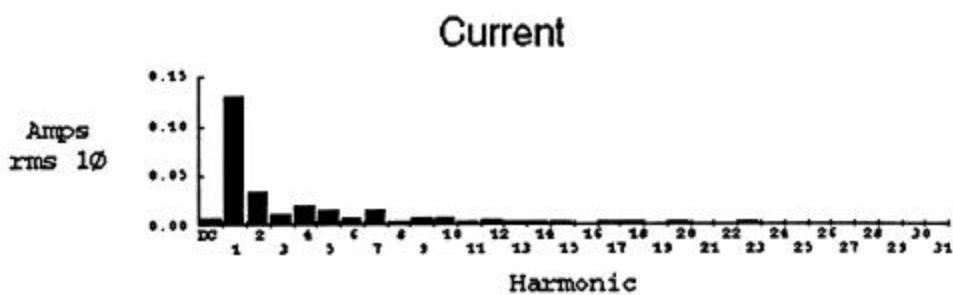
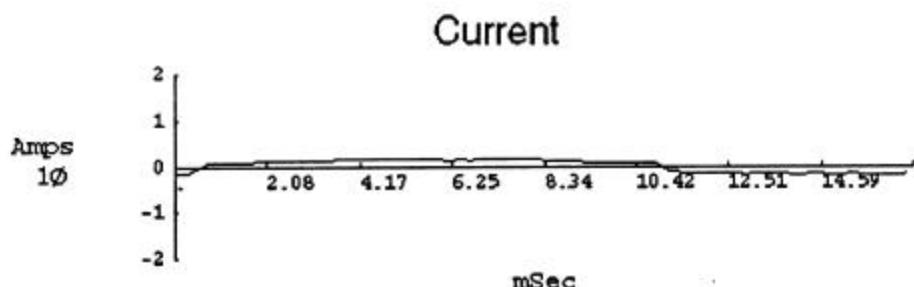
		Voltage	Current
Frequency	59.98	RMS	105.61
Power		Peak	149.52
KW	0.74	DC Offset	0.08
KVA	0.74	Crest	1.42
KVAR	0.01	THD Rms	1.85
Peak KW	1.48	THD Fund	1.85
Phase	1° lead	HRMS	1.95
Total PF	1.00	KFactor	0.12
DPF	1.00		1.01



Coffee Maker
Model - Mr. Coffee PRX23
Ratings - 120V, 1025W

Rest mode
Normal Voltage Condition

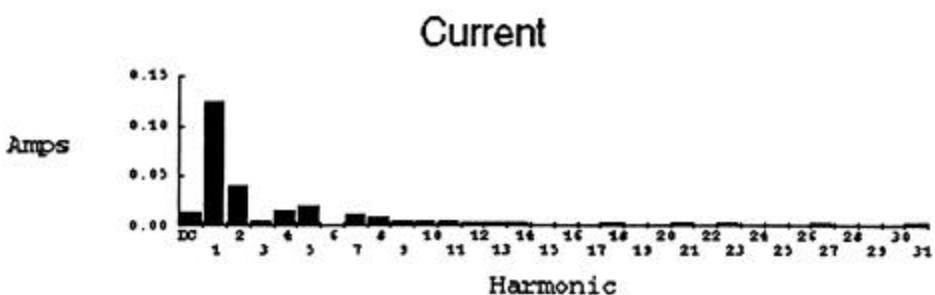
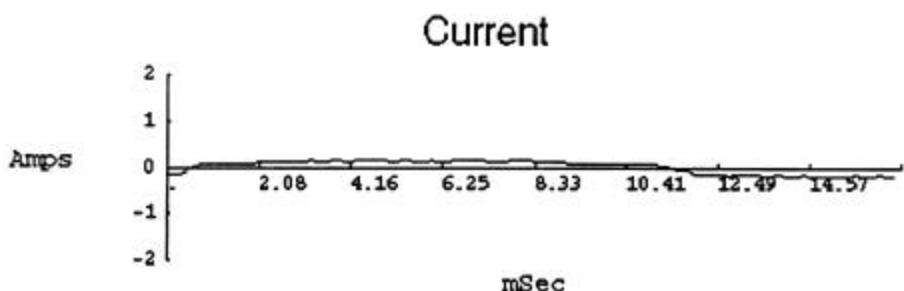
		Voltage	Current
Frequency	59.98	RMS	120.12
Power		Peak	170.00
Watts	13.76	DC Offset	0.14
VA	17.76	Crest	1.42
Vars	8.03	THD Rms	1.85
Peak W	31.54	THD Fund	1.85
Phase	34° lag	HRMS	2.22
Total PF	0.76	KFactor	5.25
DPF	0.83		



Coffee Maker
Model - Mr. Coffee PRX23
Ratings - 120V, 1025W

Rest mode
Low Voltage Condition

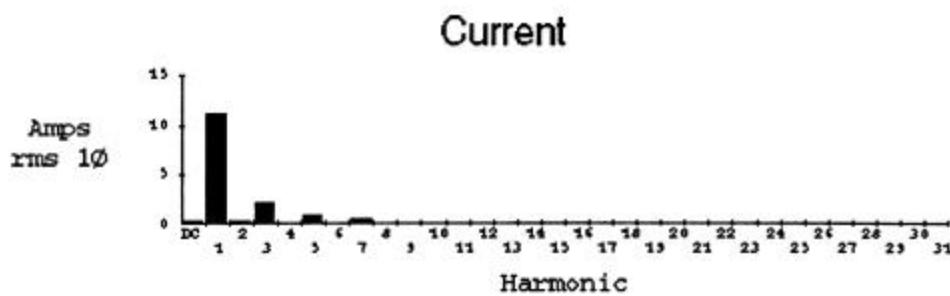
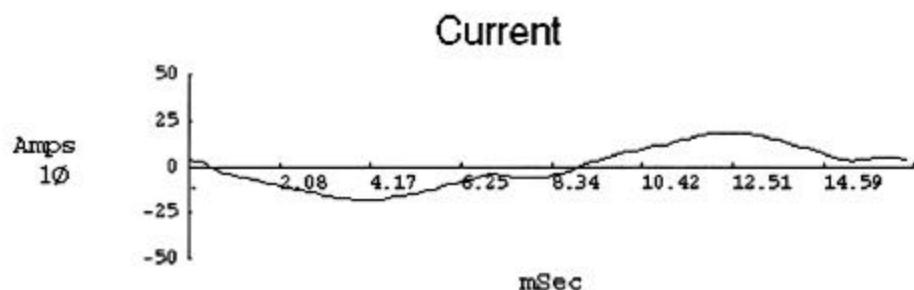
		Voltage	Current
Frequency	60.04	RMS	107.93
Power		Peak	152.78
Watts	10.45	DC Offset	0.06
VA	14.64	Crest	1.42
Vars	8.02	THD Rms	1.89
Peak W	28.97	THD Fund	1.89
Phase	40° lag	HRMS	2.04
Total PF	0.70	Kfactor	0.05
DPF	0.77		5.57



Microwave oven
Model - Sharp R-3A54
Ratings - 120V, 12 A

Normal Voltage Condition

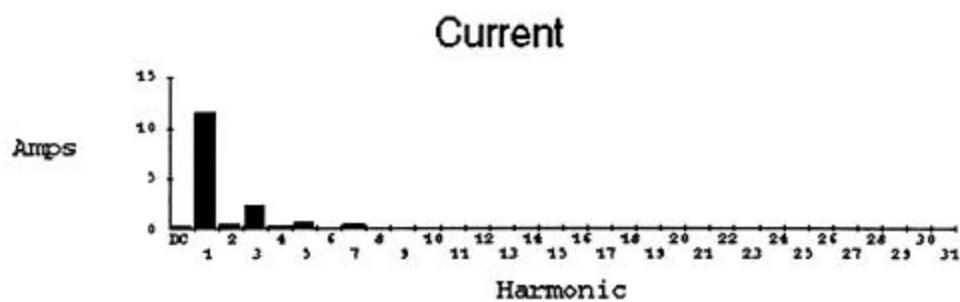
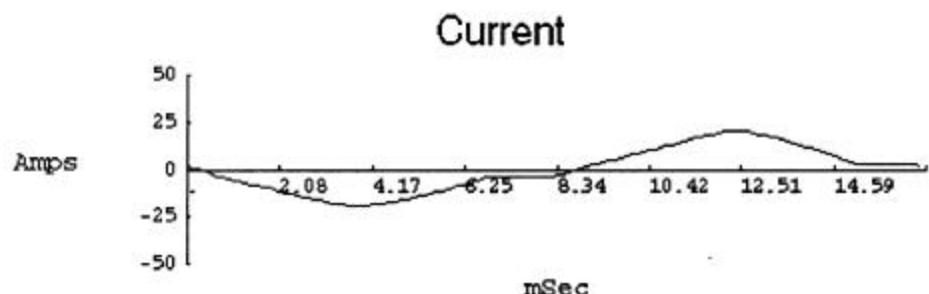
		Voltage	Current
Frequency	59.98	RMS	120.48
Power		Peak	168.34
KW	-1.34	DC Offset	0.07
KVA	1.38	Crest	1.4
KVAR	0.05	THD Rms	1.92
Peak KW	-3.18	THD Fund	1.92
Phase	178° lead	HRMS	2.32
Total PF	-0.97	KFactor	1.69
DPF	-1.00		



Microwave oven
Model - Sharp R-3A54
Ratings - 120V, 12 A

Low Voltage Condition

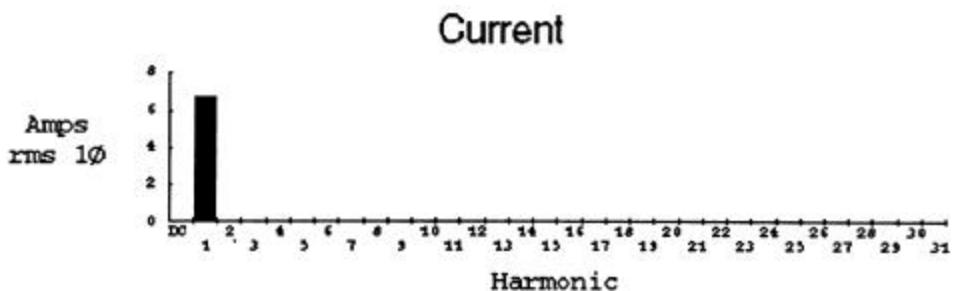
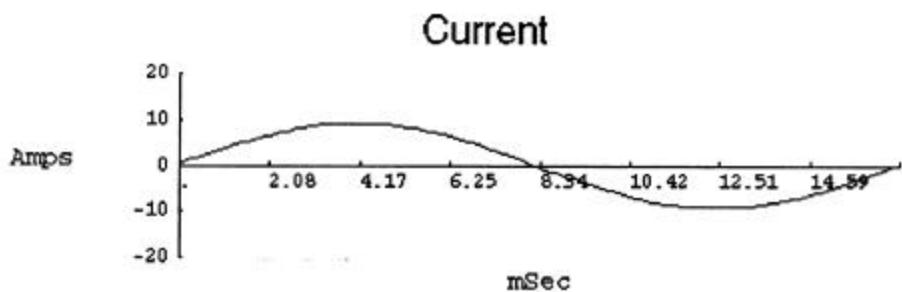
		Voltage	Current
Frequency	59.98	RMS	108.46
Power		Peak	20.08
KW	-1.25	DC Offset	0.10
KVA	1.29	Crest	1.69
KVAR	0.05	THD Rms	1.92
Peak KW	-3.12	THD Fund	21.70
Phase	178° lag	HRMS	22.23
Total PF	-0.97	KFactor	2.57
DPF	-1.00		1.57



Toaster
Model - Black and Decker
Ratings - 120V

Normal Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	116.79
Power		Peak	164.37
KW	0.79	DC Offset	0.17
KVA	0.79	Crest	1.41
KVAR 0.01		THD Rms	1.26
Peak KW	1.56	THD Fund	1.26
Phase	2°lead	HRMS	1.48
Total PF	1.00	KFactor	0.08
DPF	1.00		1.01

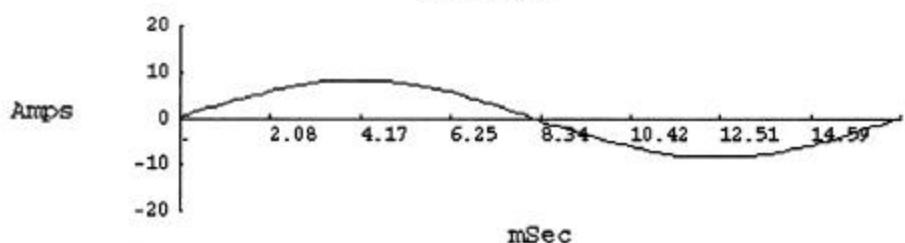


Toaster
Model - Black and Decker
Ratings - 120V

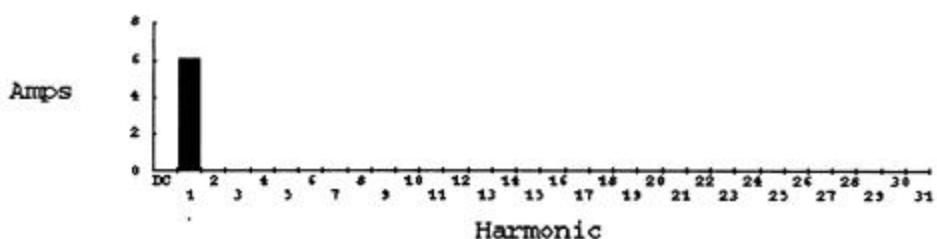
Low Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	104.16
Power		Peak	146.66
KW	0.63	DC Offset	0.13
KVA	0.63	Crest	1.41
KVAR	0.02	THD Rms	1.27
Peak KW	1.24	THD Fund	1.27
Phase	2° lead	HRMS	1.32
Total PF	1.00	KFactor	1.01
DPF	1.00		

Current



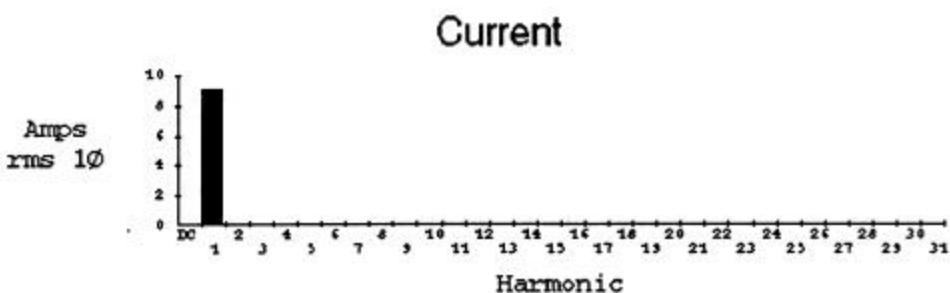
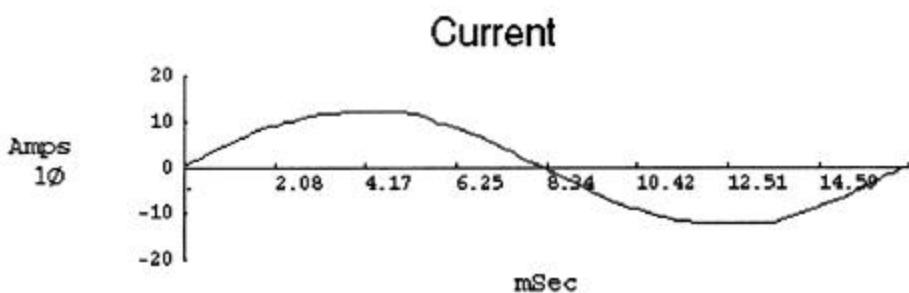
Current



Toaster
Model - Proctor Silex
Ratings - 120V

Normal Voltage Condition

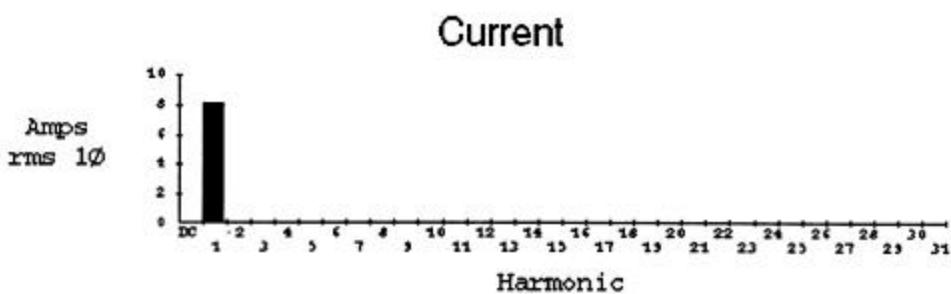
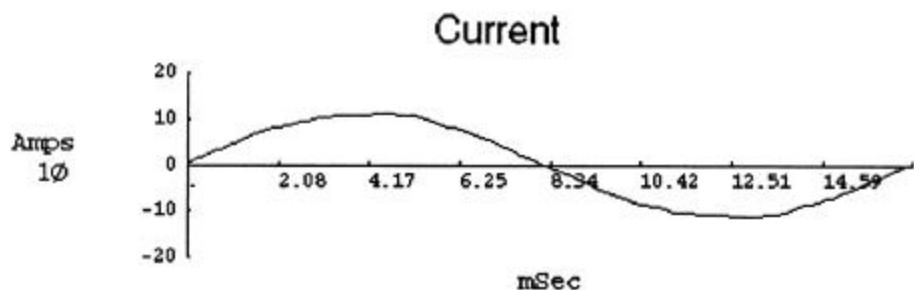
		Voltage	Current
Frequency	59.96	RMS	120.44
Power		Peak	168.94
KW	1.10	DC Offset	0.13
KVA	1.10	Crest	1.4
KVAR	0.04	THD Rms	2.56
Peak KW	2.14	THD Fund	2.56
Phase	2° lead	HRMS	3.08
Total PF	1.00	KFactor	0.22
DPF	1.00		1.03



Toaster
Model - Proctor Silex
Ratings - 120V

Low Voltage Condition

		Voltage	Current
Frequency	59.96	RMS	108.11
Power		Peak	151.71
KW	0.88	DC Offset	0.00
KVA	0.88	Crest	1.4
KVAR	0.03	THD Rms	2.59
Peak KW	1.73	THD Fund	2.59
Phase	2° lead	HRMS	2.49
Total PF	1.00	KFactor	0.20
DPF	1.00		





Appendix A.3

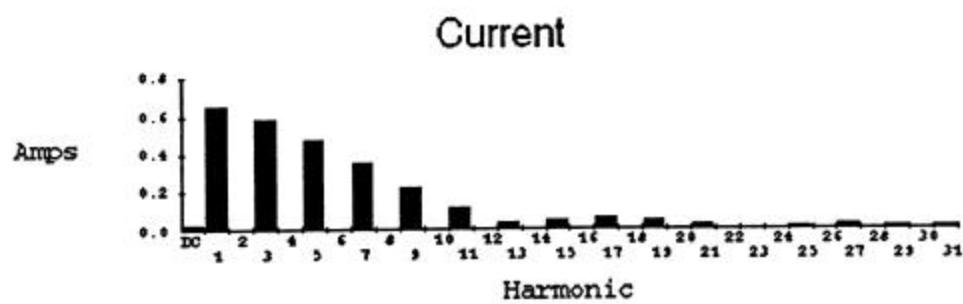
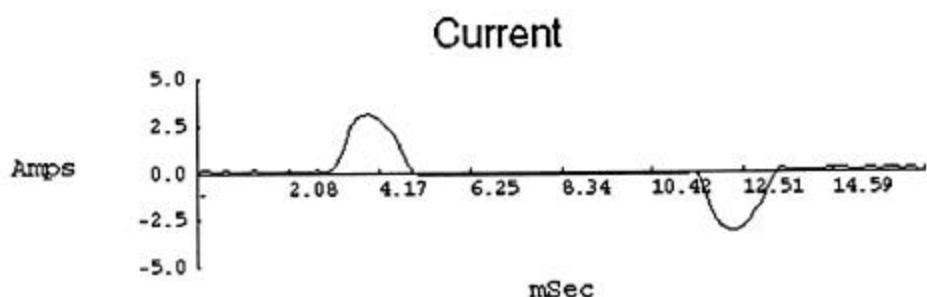
Home Entertainment



Television
Model - Sony KV27526
Ratings - 120V, 165W

Normal Voltage Condition

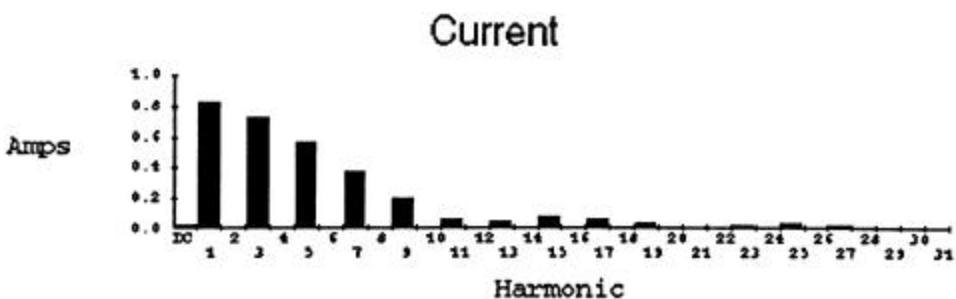
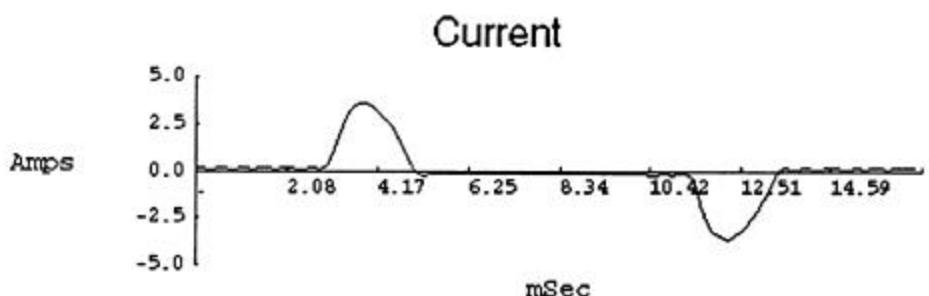
		Voltage	Current
Frequency	59.98	RMS	120.17
Power		Peak	3.22
KW	0.07	DC Offset	0.16
KVA	0.13	Crest	2.97
KVAR	0.02	THD Rms	1.38
Peak KW	0.54	THD Fund	80.40
Phase	16° lead	HRMS	135.23
Total PF	0.57	KFactor	0.87
DPF	0.96		21.17



Television
Model - Sony KV-27526
Ratings - 120V, 165W

Low Voltage Condition

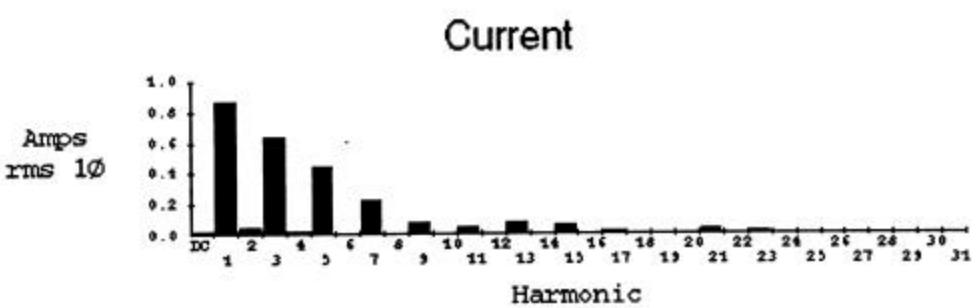
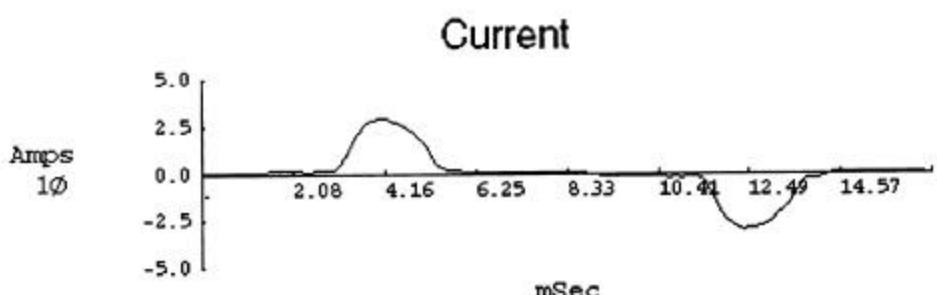
		Voltage	Current
Frequency	59.98	RMS	107.89
Power		Peak	151.27
KW	0.08	DC Offset	0.14
KVA	0.14	Crest	1.4
KVAR	0.02	THD Rms	1.41
Peak KW	0.56	THD Fund	1.41
Phase	15° lead	HRMS	1.52
Total PF	0.60	KFactor	16.90
DPF	0.97		



Television
Model - Mitsubishi CS-26EXI
Ratings - 120V, 145W (1992)

Low Voltage Condition

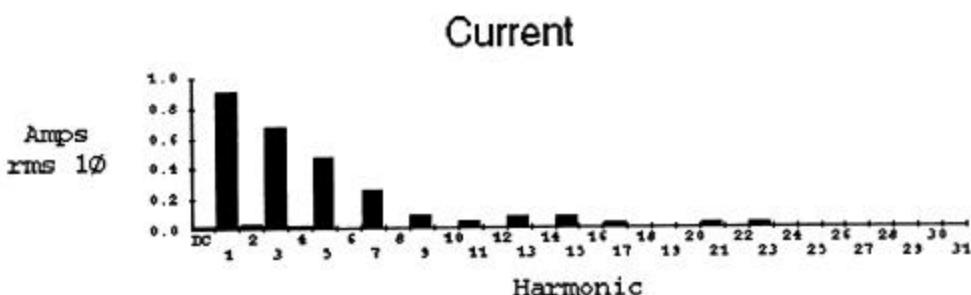
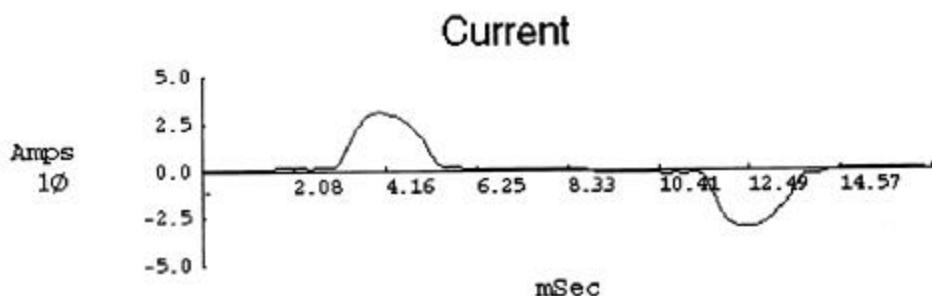
		Voltage	Current
Frequency	60.04	RMS	108.15
Power		Peak	150.55
KW	0.09	DC Offset	0.21
KVA	0.13	Crest	1.39
KVAR	0.00	THD Rms	2.28
Peak KW	0.45	THD Fund	2.28
Phase	2° lead	HRMS	2.47
Total PF	0.72	KFactor	94.56
DPF	1.00		10.60



Television
Model - Mitsubishi CS-26EXI
Ratings - 120V, 145W (1992)

Normal Voltage condition

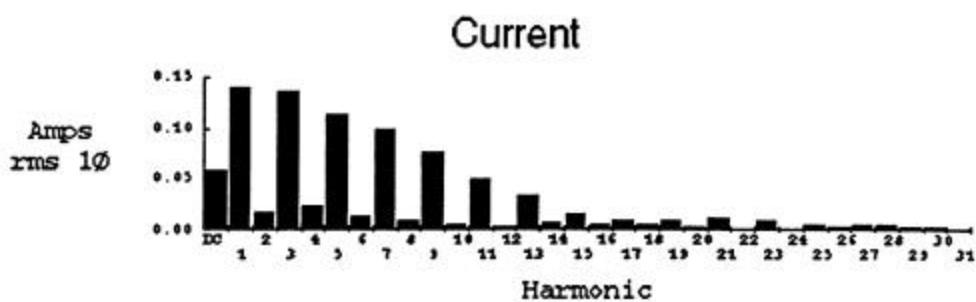
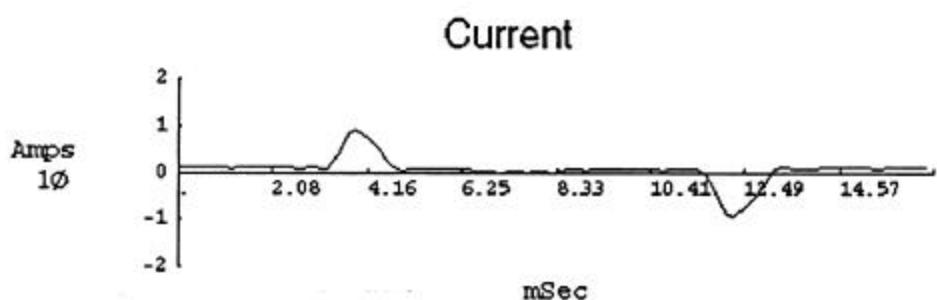
		Voltage	Current
Frequency	60.04	RMS	119.89
Power		Peak	166.86
KW	0.11	DC Offset	0.22
KVA	0.15	Crest	1.39
KVAR	0.00	THD Rms	2.24
Peak KW	0.53	THD Fund	2.24
Phase	2° lead	HRMS	2.69
Total PF	0.72	KFactor	0.87
DPF	1.00		11.29



Video Cassette Recorder (VCR)
Model - Sony SLV975HF
Ratings - 120V, 24W

Normal Voltage Condition

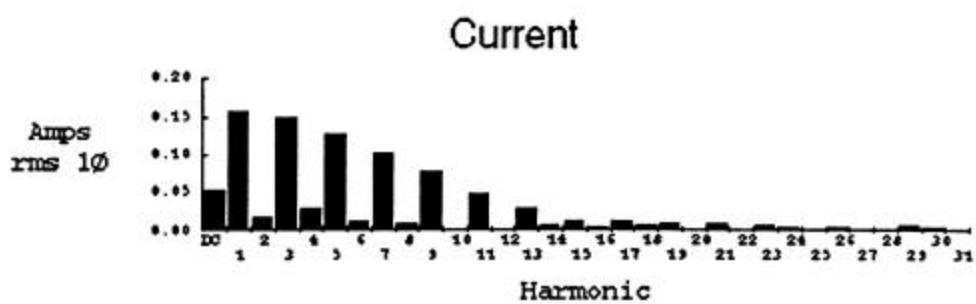
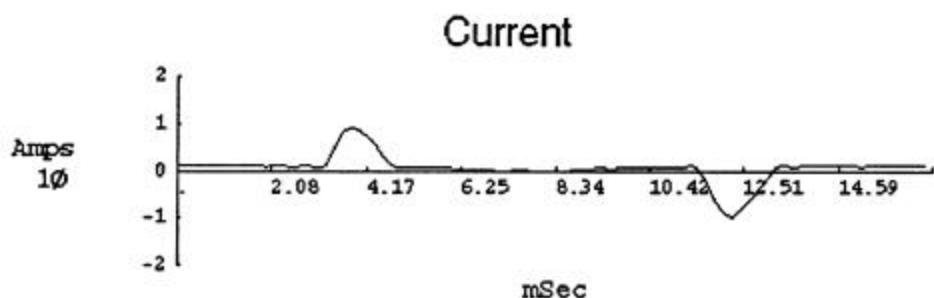
		Voltage	Current
Frequency	60.04	RMS	120.25
Power		Peak	168.52
Watts	16.09	DC Offset	0.21
VA	33.15	Crest	1.4
Vars	3.02	THD Rms	1.45
Peak W	161.59	THD Fund	1.45
Phase	13° lead	HRMS	1.75
Total PF	0.49	KFactor	0.23
DPF	0.98		**OL**



Video Cassette Recorder (VCR)
Model - Sony SLV975HF
Ratings - 120V, 24W

Low Voltage Condition

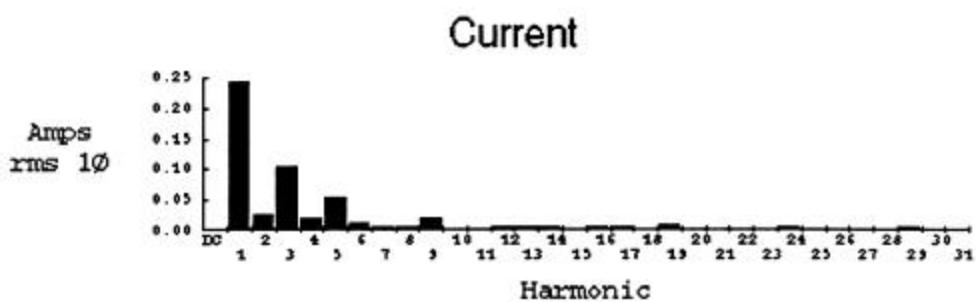
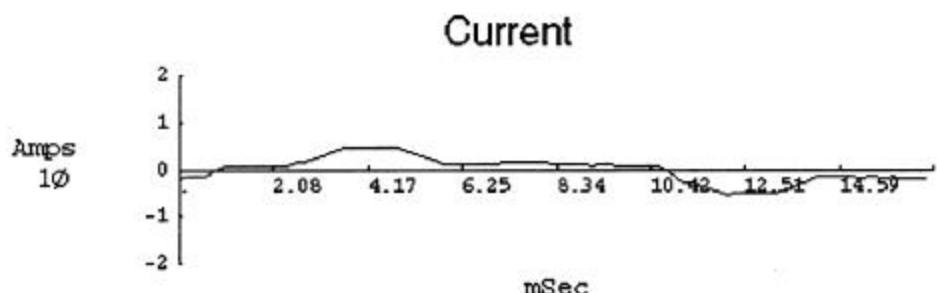
		Voltage	Current
Frequency	59.98	RMS	107.99
Power		Peak	151.41
Watts	16.09	DC Offset	0.29
VA	32.15	Crest	1.4
Vars	4.02	THD Rms	1.43
Peak W	150.59	THD Fund	1.43
Phase	15° lead	HRMS	1.54
Total PF	0.51	KFactor	27.84
DPF	0.97		



Video Cassette Recorder (VCR)
Model - Mitsubishi HS-U56
Ratings - 120V, 28W (1992)

Normal Voltage Condition

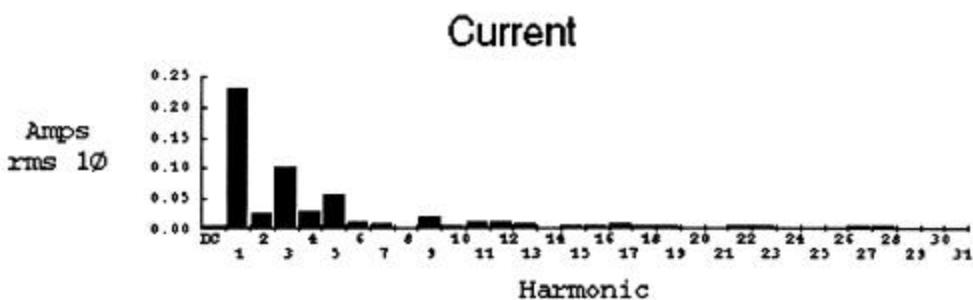
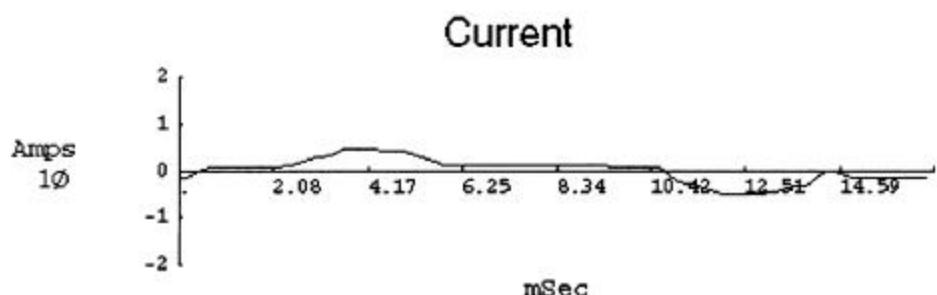
		Voltage	Current
Frequency	59.98	RMS	120.46
Power		Peak	168.69
Watts	27.10	DC Offset	0.18
VA	33.14	Crest	1.4
Vars	9.02	THD Rms	2.07
Peak W	90.46	THD Fund	2.07
Phase	19° lag	HRMS	2.50
Total PF	0.85	KFactor	0.12
DPF	0.95		4.90



Video Cassette Recorder (VCR)
Model - Mitsubishi HS-U56
Ratings - 120V, 28W (1992)

Low Voltage Condition

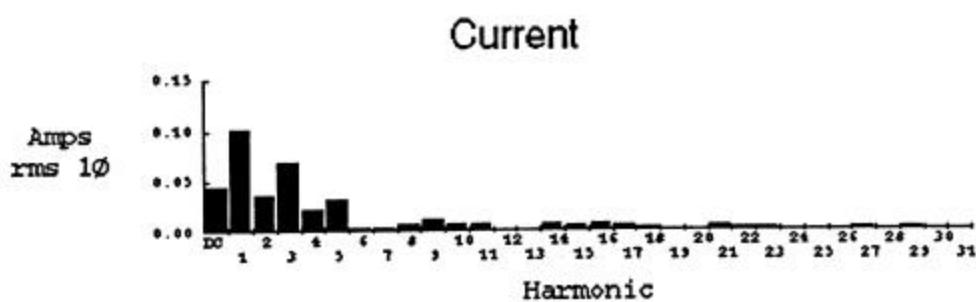
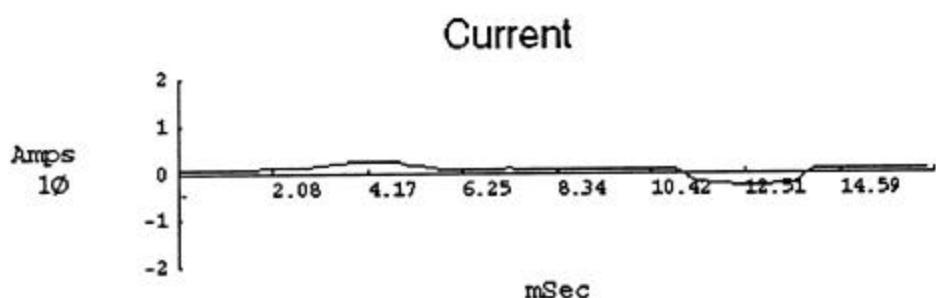
		Voltage	Current
Frequency	59.98	RMS	108.13
Power		Peak	151.47
Watts	24.10	DC Offset	0.21
VA	28.14	Crest	1.4
Vars	6.02	THD Rms	2.06
Peak W	80.46	THD Fund	2.06
Phase	15° lag	HRMS	2.23
Total PF	0.85	KFactor	0.13
DPF	0.97		6.32



Cassette Player
Model - Sony TC-WR465
Ratings - 120V, 19W

Normal Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	120.20
Power		Peak	168.75
Watts	12.09	DC Offset	0.26
VA	16.15	Crest	1.4
Vars	0.02	THD Rms	1.38
Peak W	52.59	THD Fund	1.38
Phase	0° lag	HRMS	1.66
Total PF	0.72	KFactor	0.09
DPF	1.00		10.99

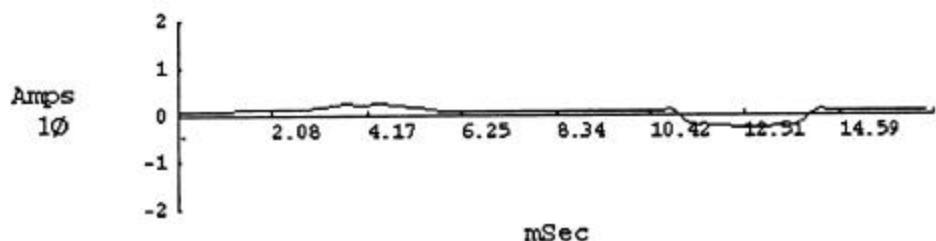


Cassette Player
Model - Sony TC-WR465
Ratings - 120V, 19W

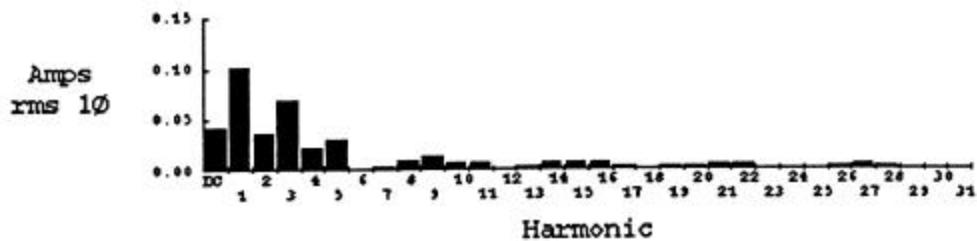
Low Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	108.10
Power		Peak	151.73
Watts	11.09	DC Offset	0.26
VA	15.15	Crest	1.4
Vars	0.02	THD Rms	1.36
Peak W	45.59	THD Fund	1.36
Phase	1° lead	HRMS	1.47
Total PF	0.73	KFactor	12.81
DPF	1.00		

Current



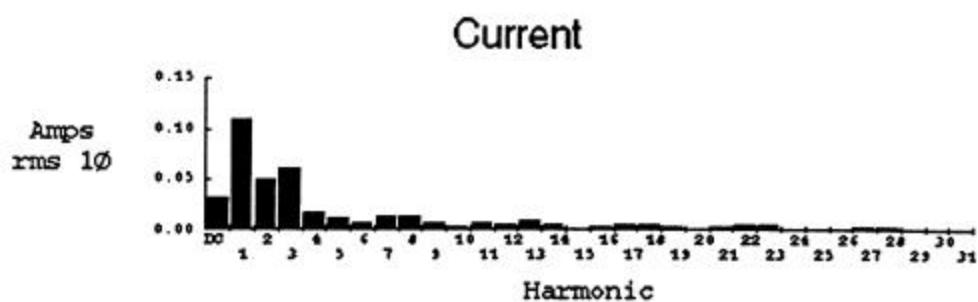
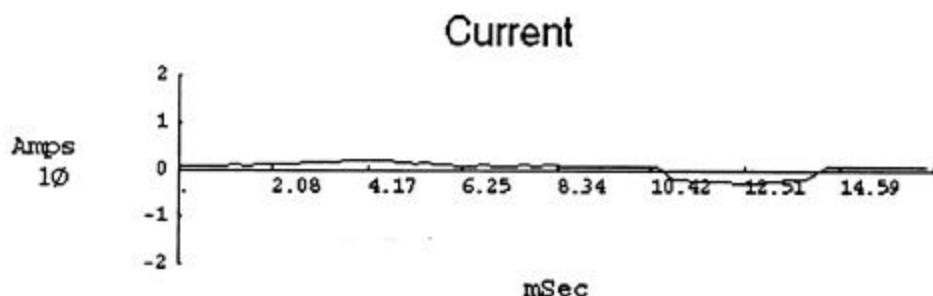
Current



CD Player
Model - Sony CDP-C265
Ratings - 120V, 24W

Normal Voltage Condition

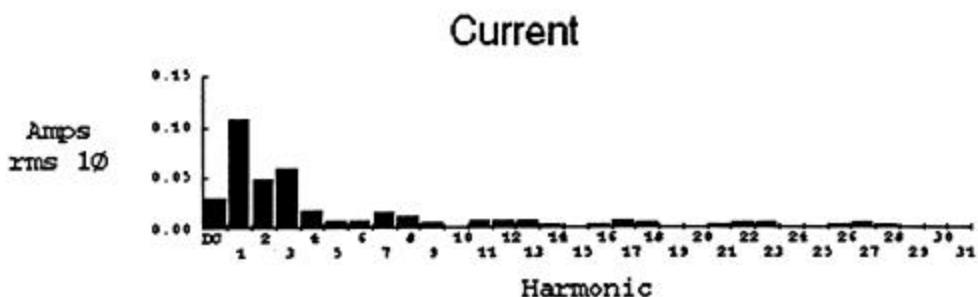
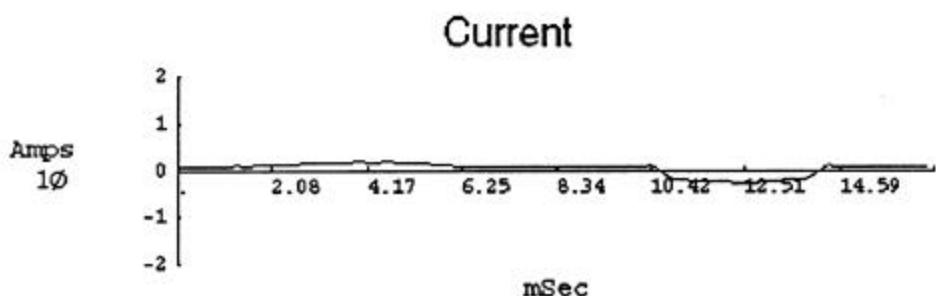
		Voltage	Current
Frequency	59.98	RMS	120.22
Power		Peak	168.66
Watts	13.09	DC Offset	0.28
VA	17.15	Crest	1.4
Vars	0.02	THD Rms	1.39
Peak W	49.59	THD Fund	1.39
Phase	2° lead	HRMS	1.68
Total PF	0.78	KFactor	0.09
DPF	1.00		9.72



CD Player
Model - Sony CDP-C265
Ratings - 120V, 24W

Low Voltage Condition

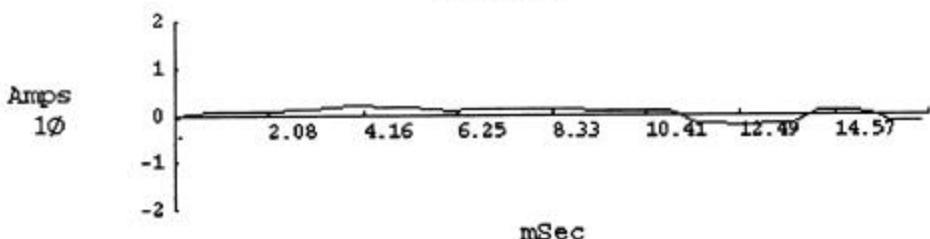
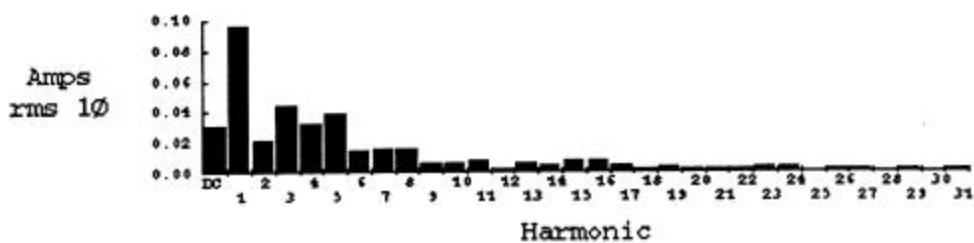
		Voltage	Current
Frequency	59.98	RMS	108.37
Power		Peak	152.16
Watts	11.09	DC Offset	0.26
VA	15.15	Crest	1.4
Vars	0.02	THD Rms	1.41
Peak W	42.59	THD Fund	1.41
Phase	4° lead	HRMS	1.53
Total PF	0.78	Kfactor	0.08
DPF	1.00		10.60



CD Player**Model - Sharp DX-3510 (BK)****Ratings - 120V, 11W (Yr-1989)**

Normal Voltage Condition

			Voltage	Current
Frequency	60.04	RMS	119.34	0.13
Power		Peak	167.23	0.23
Watts	10.10	DC Offset	0.17	0.03
VA	15.14	Crest	1.4	1.73
Vars	4.02	THD Rms	2.12	63.35
Peak W	41.46	THD Fund	2.12	81.88
Phase	22° lag	HRMS	2.53	0.08
Total PF	0.70	KFactor	14.16	
DPF	0.93			

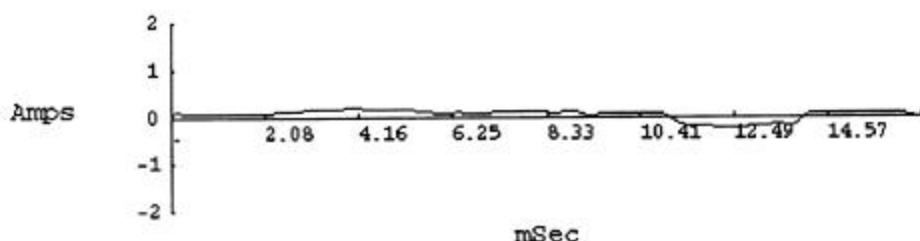
Current**Current**

CD Player
Model - Sharp DX-3510 (BK)
Ratings - 120V, 11W (Yr-1989)

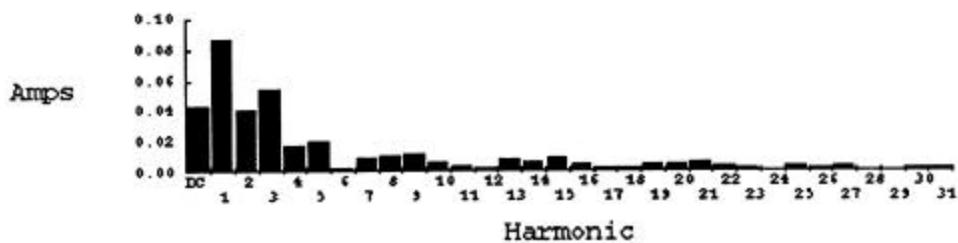
Low Voltage Condition

			Voltage	Current
Frequency	60.04	RMS	107.81	0.13
Power		Peak	150.95	0.22
Watts	9.10	DC Offset	0.22	0.04
VA	13.14	Crest	1.4	1.73
Vars	0.02	THD Rms	2.19	66.00
Peak W	35.46	THD Fund	2.19	87.85
Phase	5° lag	HRMS	2.36	0.08
Total PF	0.71	KFactor	13.98	
DPF	1.00			

Current



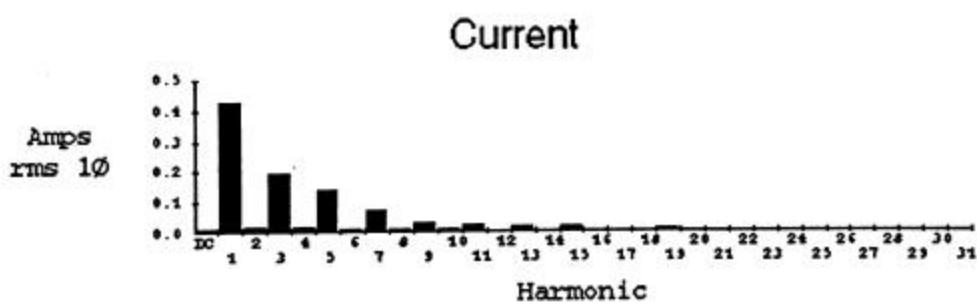
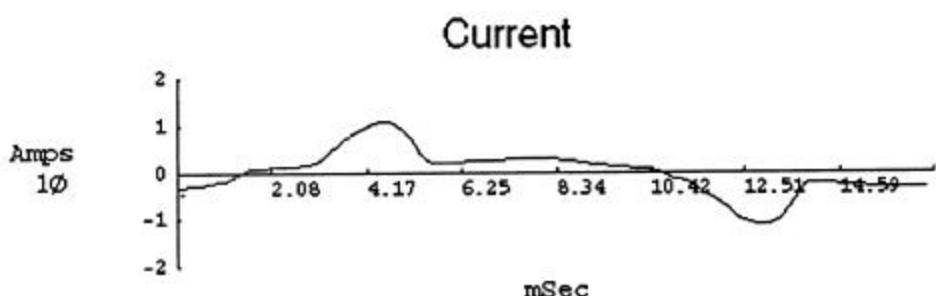
Current



Sound Amplifier
Model - Kenwood KR-A3070
Ratings 120V, 120W

Normal Voltage Condition

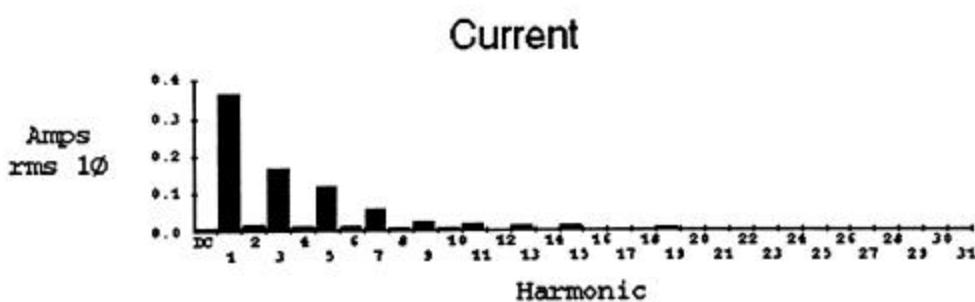
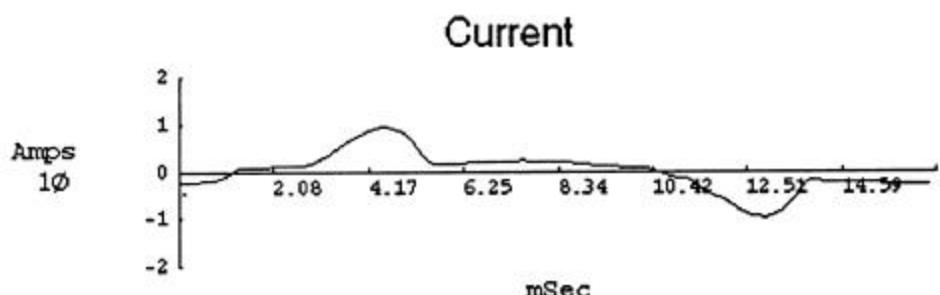
		Voltage	Current
Frequency	59.98	RMS	119.98
Power		Peak	168.16
Watts	46.09	DC Offset	0.12
VA	60.15	Crest	1.4
Vars	21.02	THD Rms	1.39
Peak W	195.59	THD Fund	1.39
Phase	25° lag	HRMS	1.67
Total PF	0.76	KFactor	6.48
DPF	0.90		



Sound Amplifier
Model - Kenwood KR-A3070
Ratings 120V, 120W

Low Voltage Condition

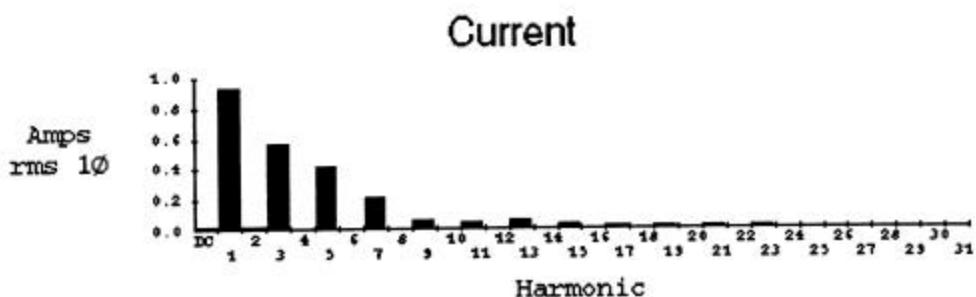
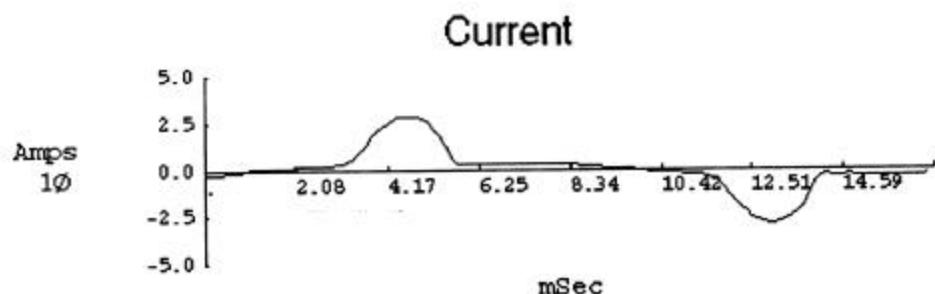
		Voltage	Current
Frequency	59.98	RMS	108.01
Power		Peak	151.34
Watts	36.09	DC Offset	0.11
VA	46.15	Crest	1.4
Vars	14.02	THD Rms	1.38
Peak W	148.59	THD Fund	1.38
Phase	22° lag	HRMS	1.49
Total PF	0.78	KFactor	0.22
DPF	0.93		6.53



Stereo
Model Kenwood KR-A3070
Ratings - 120V, 120W

Normal Voltage Condition

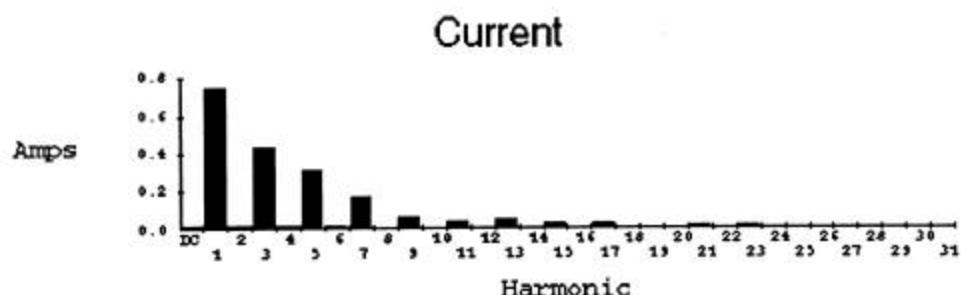
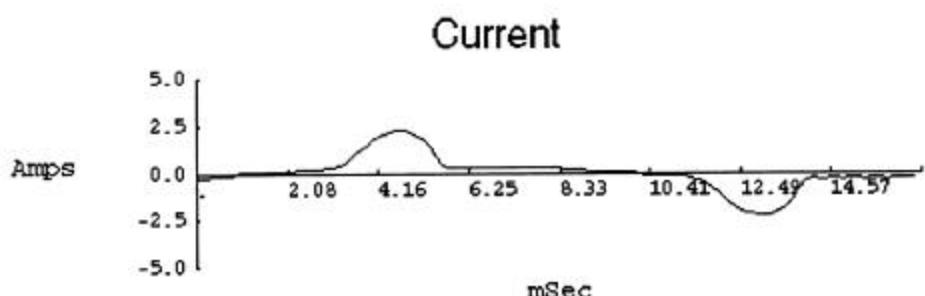
		Voltage	Current
Frequency	59.98	RMS	120.12
Power		Peak	2.95
KW	0.11	DC Offset	0.22
KVA	0.14	Crest	1.39
KVAR	0.03	THD Rms	2.08
Peak KW	0.49	THD Fund	2.08
Phase	14° lag	HRMS	2.50
Total PF	0.76	KFactor	0.74
DPF	0.97		8.65



Stereo
Model Kenwood KR-A3070
Ratings - 120V, 120W

Low Voltage Condition

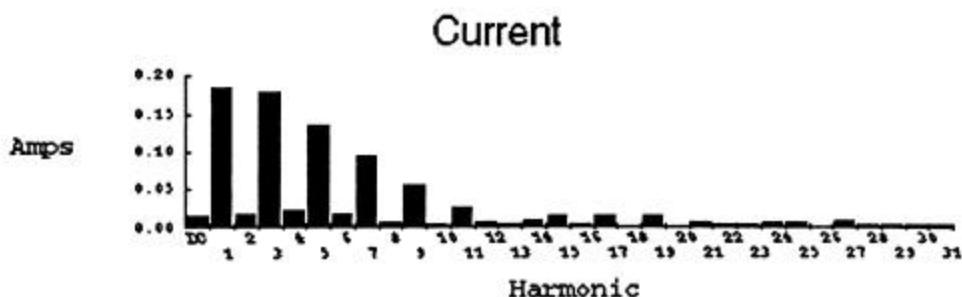
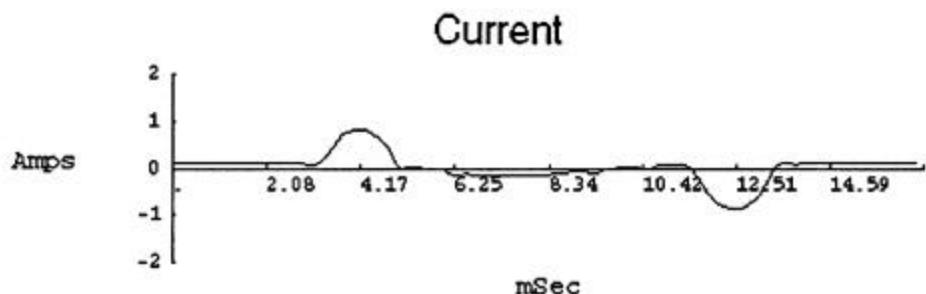
		Voltage	Current
Frequency	60.04	RMS	108.36
Power		Peak	150.99
Watts	78.10	DC Offset	0.11
VA	102.14	Crest	2.47
Vars	20.02	THD Rms	2.20
Peak W	353.46	THD Fund	2.20
Phase	15° lag	HRMS	2.39
Total PF	0.77	KFactor	0.57
DPF	0.97		8.63



Satellite Dish Receiver
Model - Echostar 3000
Ratings - 117V, 45W

Normal Voltage Condition

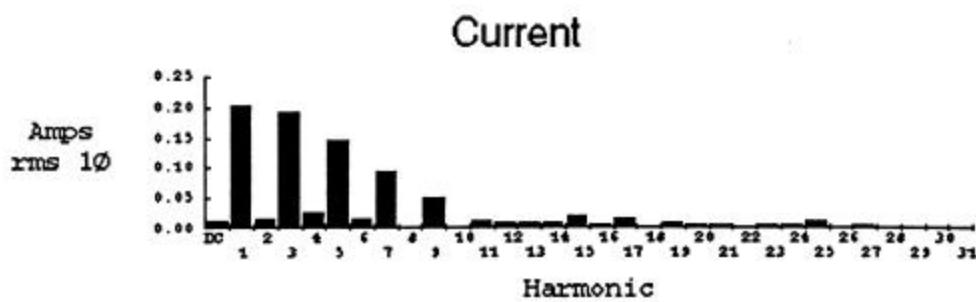
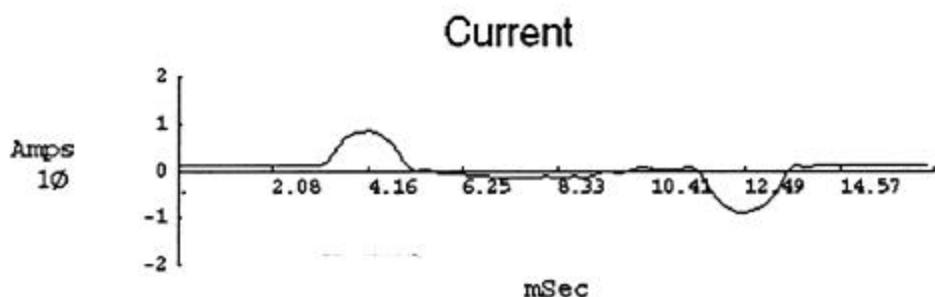
		Voltage	Current
Frequency	59.98	RMS	120.00
Power		Peak	168.38
Watts	19.00	DC Offset	0.23
VA	37.00	Crest	1.4
Vars	9.00	THD Rms	1.36
Peak W	151.00	THD Fund	1.36
Phase	25° lead	HRMS	1.64
Total PF	0.53	KFactor	20.25
DPF	0.90		



Satellite Dish Receiver
Model - Echostar 3000
Ratings - 117V, 45W

Low Voltage Condition

		Voltage	Current
Frequency	60.04	RMS	108.50
Power		Peak	152.01
Watts	20.00	DC Offset	0.16
VA	36.00	Crest	1.4
Vars	8.00	THD Rms	1.46
Peak W	142.00	THD Fund	1.46
Phase	23° lead	HRMS	1.58
Total PF	0.55	KFactor	17.51
DPF	0.92		





Appendix A.4

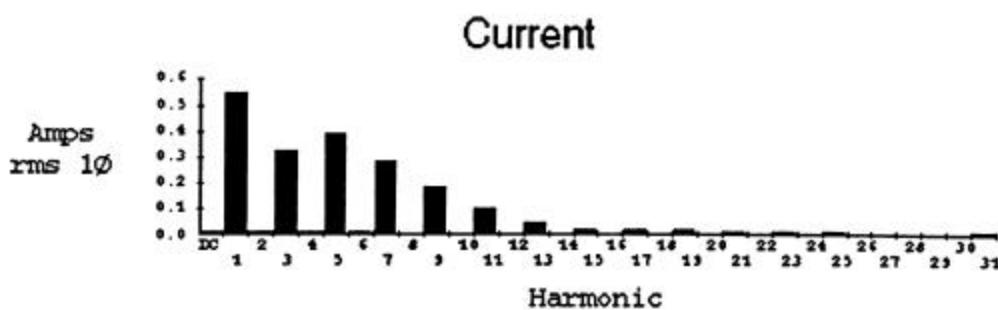
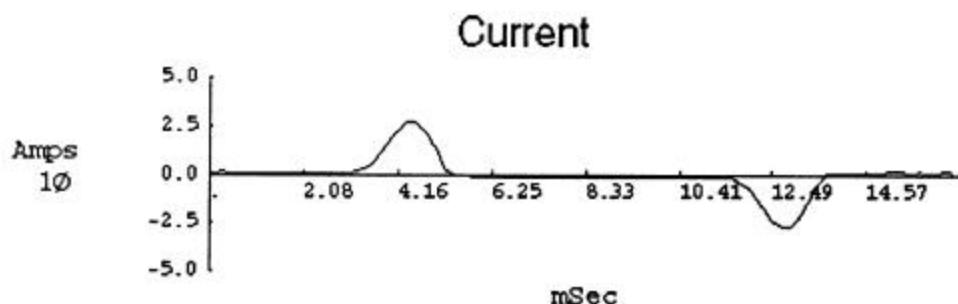
Home Office



Computer (Hard disk drive)
Model - Apple Power Macintosh 8500 M3409
Ratings - 120V, 9A

Normal Voltage Condition

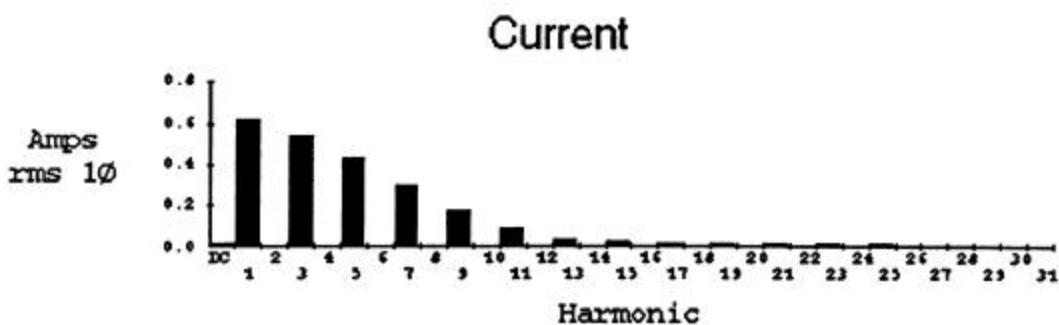
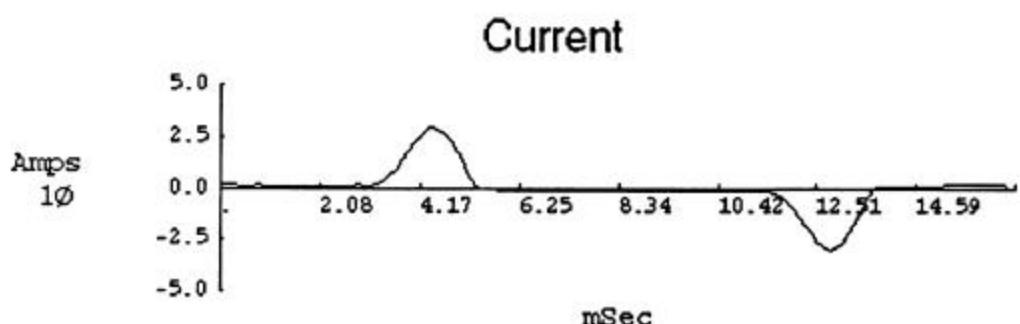
		Voltage	Current
Frequency	60.04	RMS	120.13
Power		Peak	167.27
KW	0.06	DC Offset	0.02
KVA	0.11	Crest	1.39
KVAR	0.01	THD Rms	1.61
Peak KW	0.47	THD Fund	1.61
Phase	9° lead	HRMS	131.91
Total PF	0.59	KFactor	0.71
DPF	0.99		18.89



Computer (Hard disk drive)
Model - Apple Power Macintosh 8500 M3409
Ratings - 120V, 9A

Low Voltage Condition

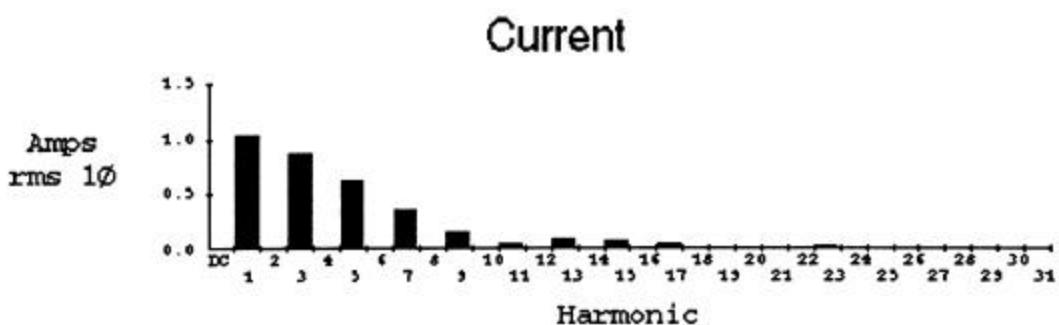
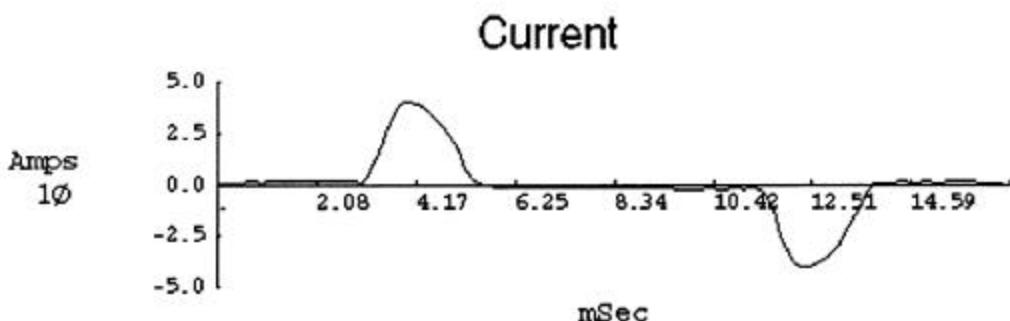
		Voltage	Current
Frequency	59.98	RMS	108.43
Power		Peak	150.94
KW	0.07	DC Offset	0.10
KVA	0.11	Crest	1.39
KVAR	0.01	THD Rms	1.57
Peak KW	0.46	THD Fund	1.57
Phase	8° lead	HRMS	1.70
Total PF	0.61	KFactor	16.94
DPF	0.99		



Computer (Hard Disk Drive)
Model - Gateway G6-333
Ratings - 100-120V, 5A (Yr-1998)

Normal Voltage Condition

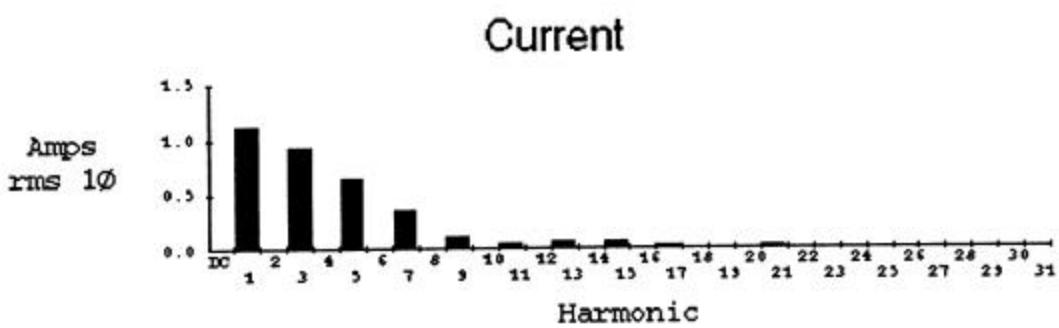
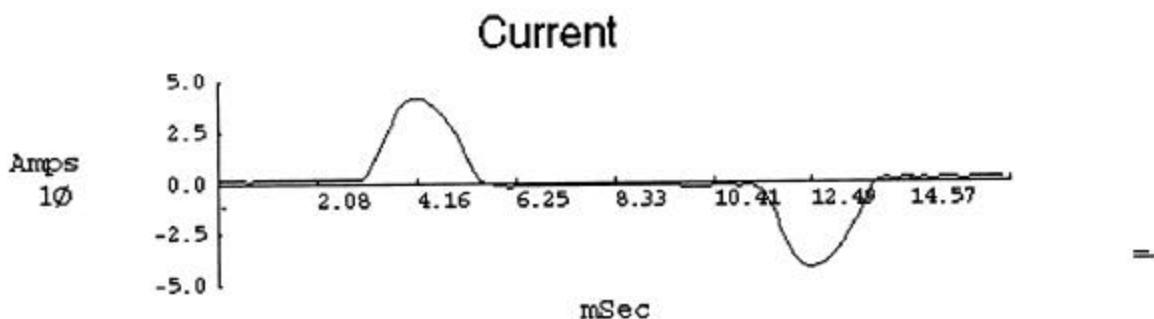
		Voltage	Current
Frequency	59.98	RMS	120.23
Power		Peak	167.63
KW	0.12	DC Offset	0.22
KVA	0.18	Crest	1.39
KVAR	0.01	THD Rms	2.18
Peak KW	0.69	THD Fund	2.18
Phase	7° lead	HRMS	2.62
Total PF	0.66	KFactor	12.82
DPF	0.99		



Computer (Hard Disk Drive)
Model - Gateway G6-333
Ratings - 100-120V, 5A (Yr-1998)

Low Voltage Condition

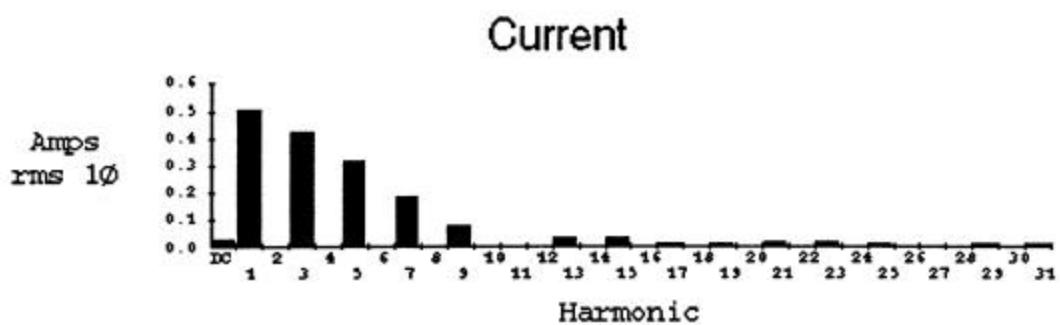
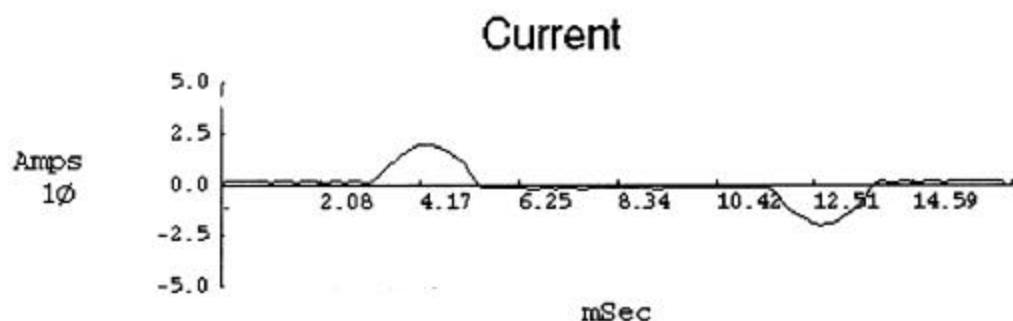
		Voltage	Current
Frequency	60.04	RMS	108.24
Power		Peak	150.48
KW	0.12	DC Offset	0.09
KVA	0.18	Crest	1.39
KVAR	0.01	THD Rms	2.44
Peak KW	0.65	THD Fund	2.44
Phase	6° lead	HRMS	2.64
Total PF	0.67	KFactor	11.15
DPF	0.99		



Computer (Hard Disk Drive)
Model - IBM Aptiva S76, 200 MHz
Ratings - 120V

Normal Voltage Condition

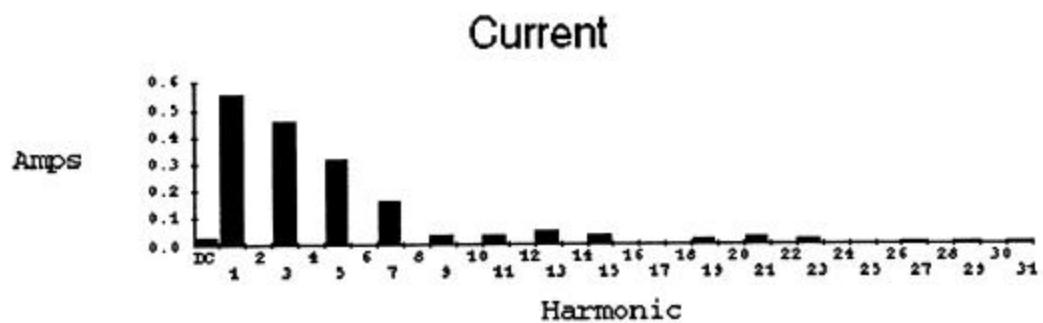
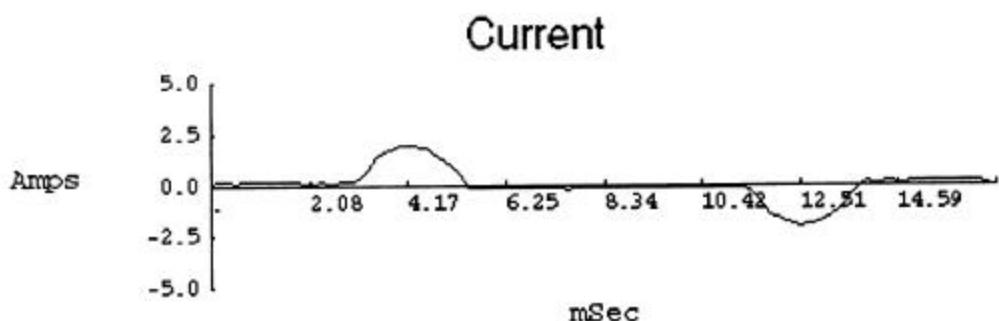
		Voltage	Current
Frequency	59.96	RMS	120.14
Power		Peak	166.25
Watts	58.00	DC Offset	0.06
VA	91.00	Crest	2.65
Vars	14.00	THD Rms	3.29
Peak W	335.00	THD Fund	3.30
Phase	14° lead	HRMS	3.96
Total PF	0.64	KFactor	0.57
DPF	0.97		13.26



Computer (Hard Disk Drive)
Model - IBM Aptiva S76, 200 MHz
Ratings - 120V

Low Voltage Condition

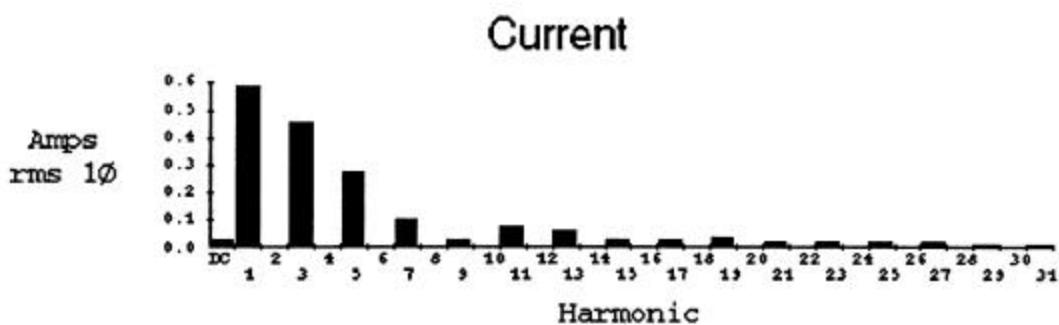
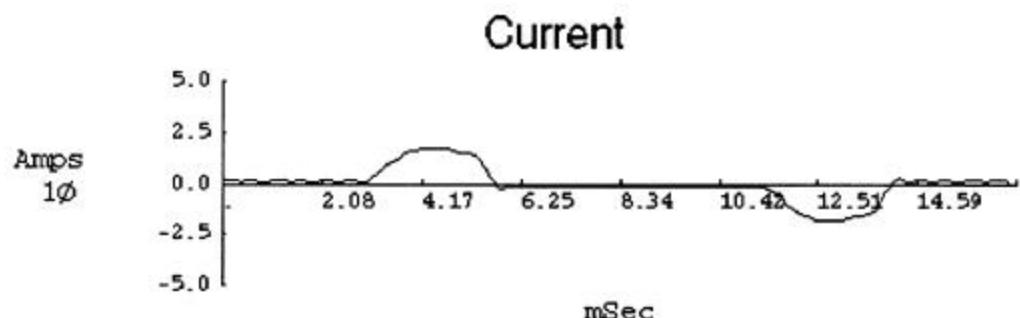
		Voltage	Current
Frequency	59.96	RMS	108.21
Power		Peak	150.05
Watts	57.00	DC Offset	0.04
VA	87.00	Crest	1.39
Vars	14.00	THD Rms	3.32
Peak W	301.00	THD Fund	72.37
Phase	14° lead	HRMS	0.58
Total PF	0.66	KFactor	12.01
DPF	0.97		



Computer (Hard Disk Drive)
Model - Dell Optiplex, 300MHz
Ratings - 120V

Normal Voltage Condition

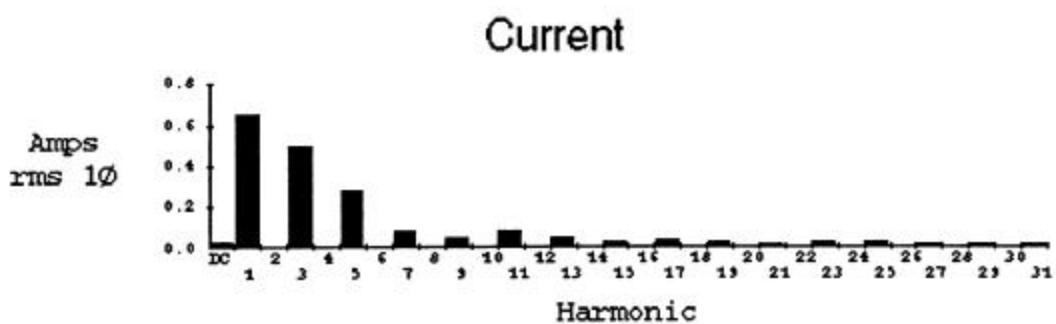
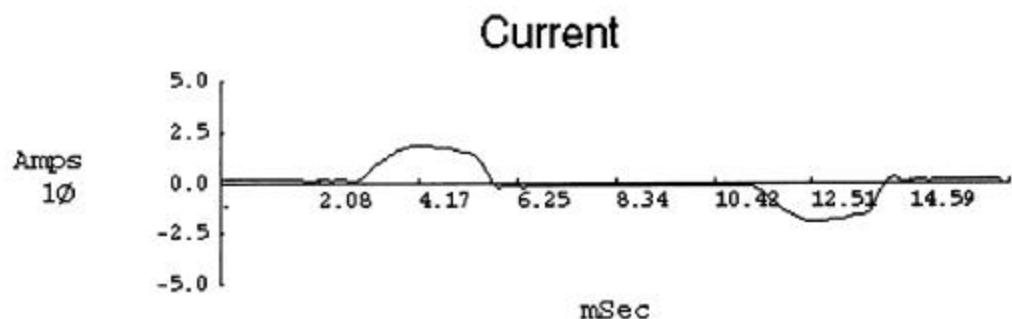
		Voltage	Current
Frequency	59.98	RMS	120.24
Power		Peak	162.54
Watts	68.00	DC Offset	0.09
VA	97.00	Crest	1.35
Vars	9.00	THD Rms	3.90
Peak W	301.00	THD Fund	3.90
Phase	8° lead	HRMS	4.69
Total PF	0.70	KFactor	12.32
DPF	0.99		



Computer (Hard Disk Drive)
Model - Dell Optiplex, 300MHz
Ratings - 120V

Low Voltage Condition

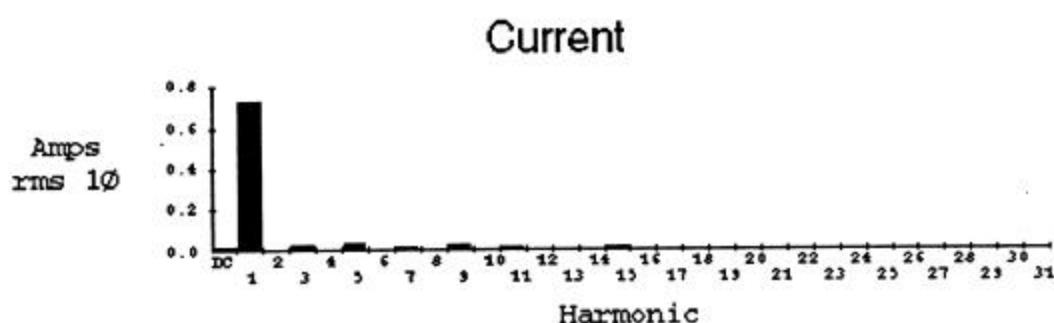
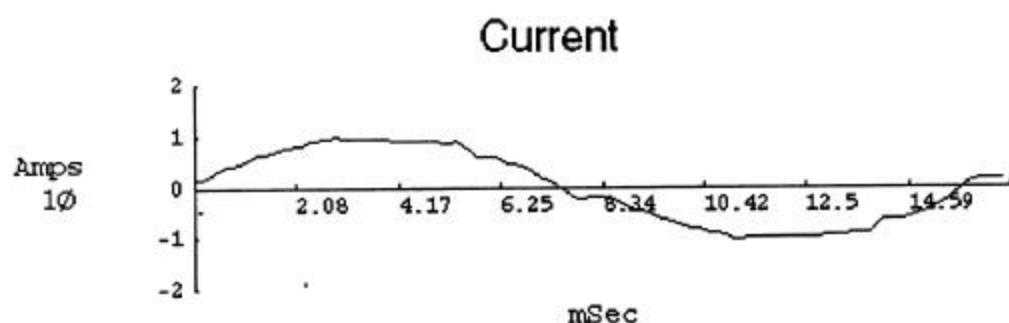
		Voltage	Current
Frequency	59.98	RMS	107.77
Power		Peak	145.50
Watts	67.00	DC Offset	0.05
VA	94.00	Crest	2.24
Vars	9.00	THD Rms	4.20
Peak W	288.00	THD Fund	4.20
Phase	8° lead	HRMS	4.52
Total PF	0.72	KFactor	0.59
DPF	0.99		11.08



Computer (Hard Disk Drive)
Model - Sun UltraSPARC
Ratings - 120V

Normal Voltage Condition

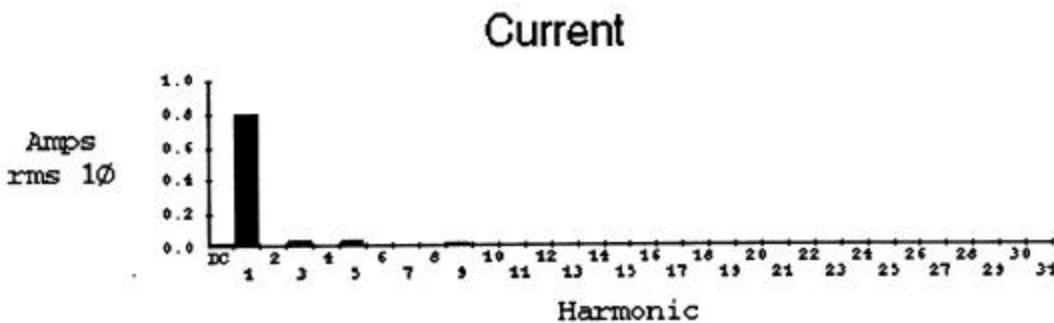
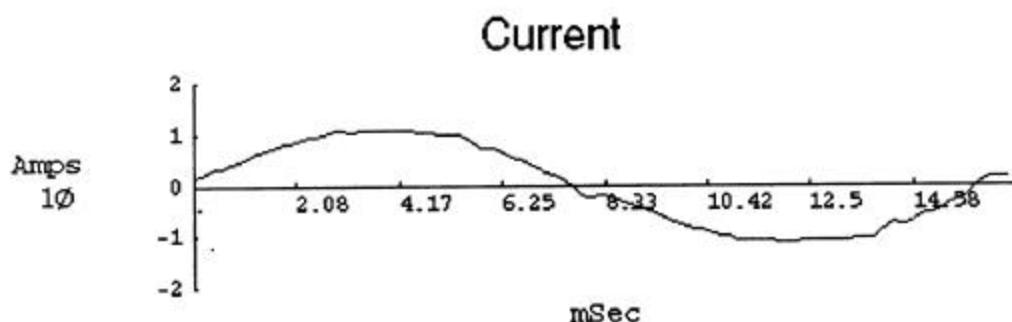
		Voltage	Current
Frequency	59.98	RMS	121.21
Power		Peak	163.88
Watts	85.18	DC Offset	0.07
VA	88.26	Crest	1.35
Vars	19.01	THD Rms	3.97
Peak W	164.41	THD Fund	3.97
Phase	13° lead	HRMS	4.81
Total PF	0.97	KFactor	0.06
DPF	0.98		1.78



Computer (Hard Disk Drive)
Model - Sun UltraSPARC
Ratings - 120V

Low Voltage Condition

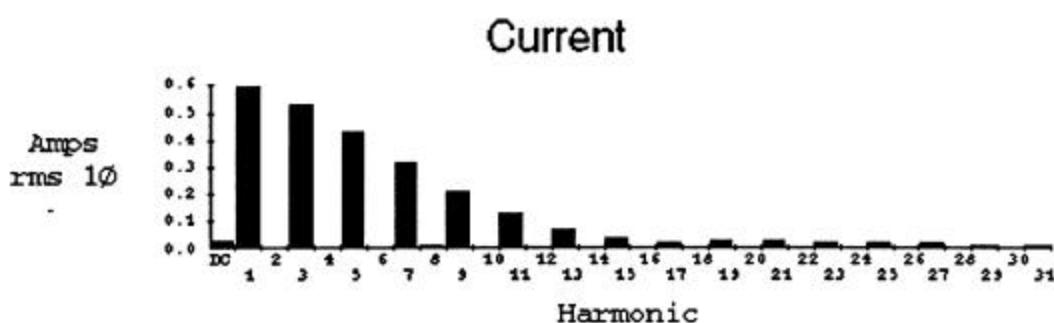
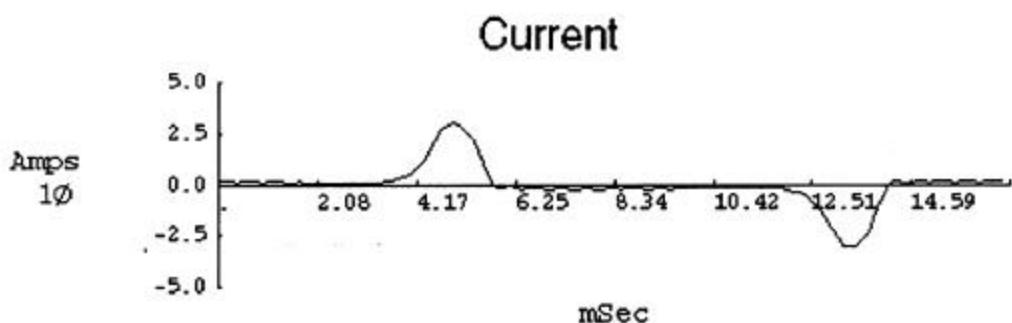
		Voltage	Current
Frequency	60.00	RMS	108.14
Power		Peak	146.11
Watts	85.18	DC Offset	0.06
VA	87.26	Crest	1.35
Vars	16.01	THD Rms	3.96
Peak W	163.41	THD Fund	3.96
Phase	11° lead	HRMS	4.28
Total PF	0.98	KFactor	0.06
DPF	0.98		1.49



Computer (Hard Disk Drive)
Model - HP Apollo 700
Ratings - 120V

Normal Voltage Condition

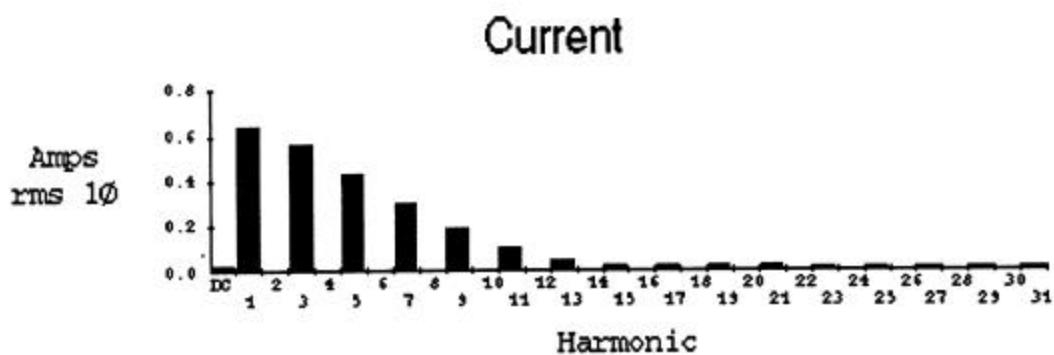
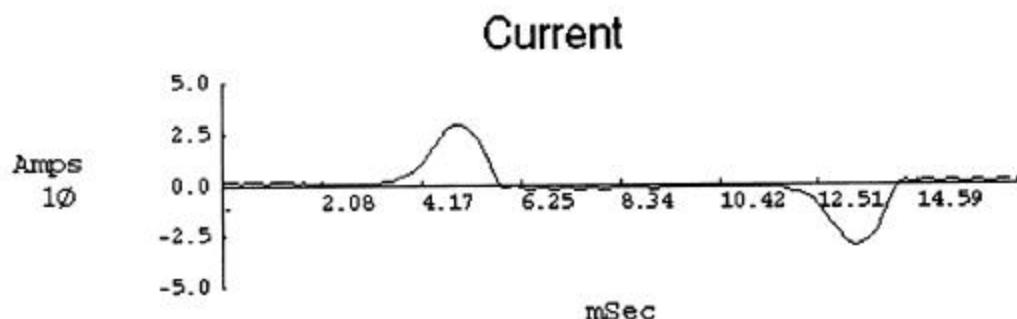
		Voltage	Current
Frequency	59.96	RMS	119.68
Power		Peak	165.27
KW	0.07	DC Offset	0.05
KVA	0.12	Crest	1.38
KVAR	0.00	THD Rms	3.05
Peak KW	0.52	THD Fund	3.05
Phase	2° lag	HRMS	3.65
Total PF	0.60	KFactor	21.20
DPF	1.00		



Computer (Hard Disk Drive)
Model - HP Apollo 700
Ratings - 120V

Low Voltage Condition

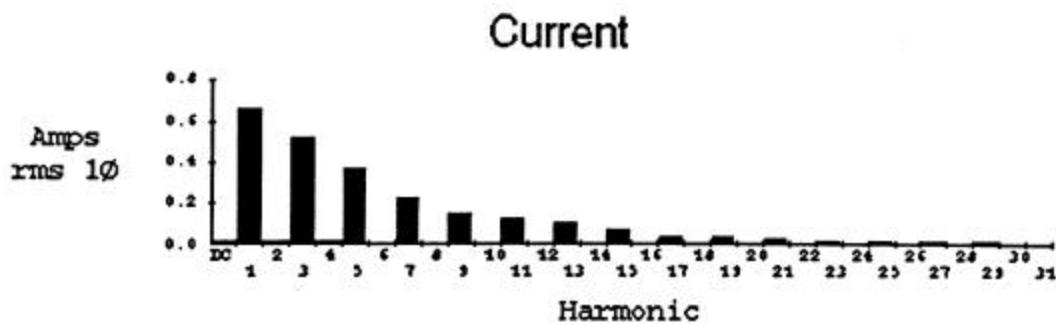
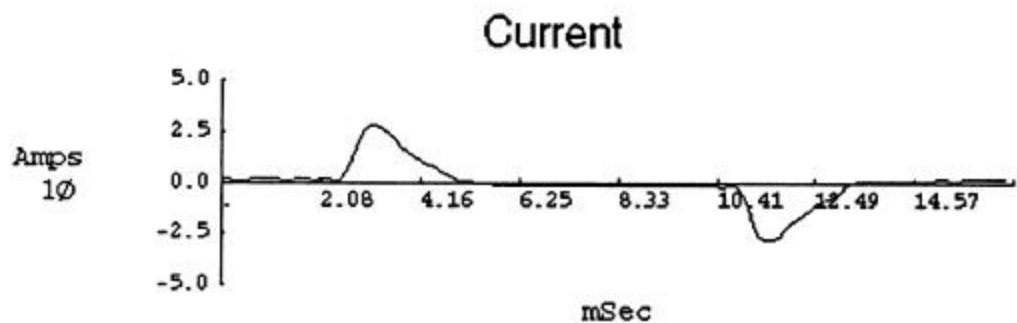
		Voltage	Current
Frequency	59.96	RMS	107.61
Power		Peak	148.16
KW	0.07	DC Offset	0.02
KVA	0.11	Crest	2.99
KVAR	0.00	THD Rms	3.19
Peak KW	0.46	THD Fund	3.19
Phase	2° lag	HRMS	3.43
Total PF	0.63	KFactor	126.40
DPF	1.00		0.80
			18.07



Computer Monitor
Model - Apple M2943
Ratings - 120V, 90W

Normal Voltage Condition

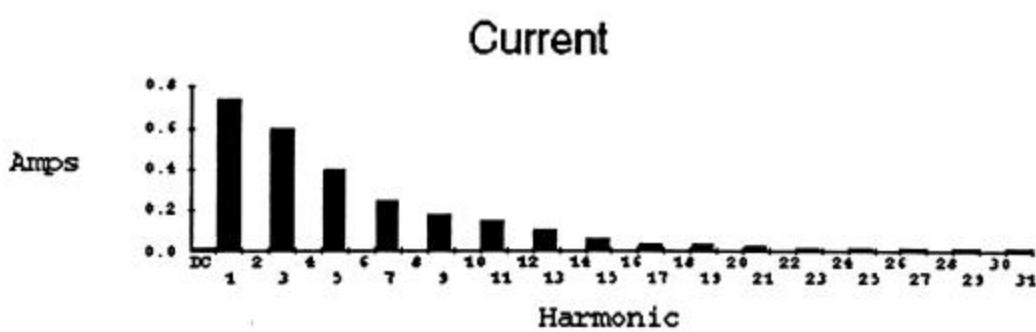
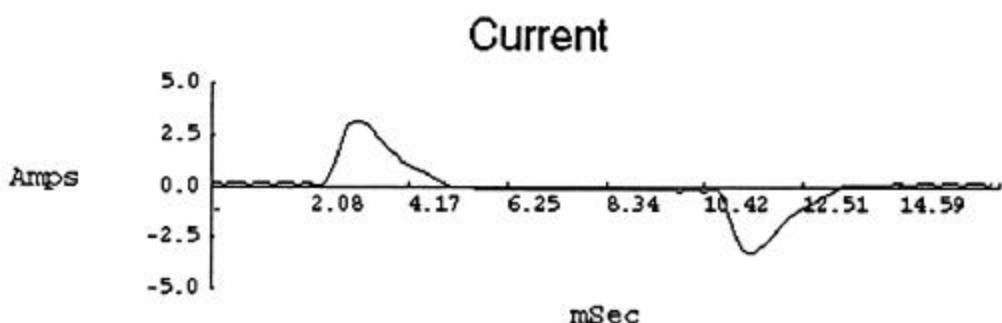
		Voltage	Current
Frequency	60.04	RMS	119.87
Power		Peak	167.89
Watts	71.07	DC Offset	0.02
VA	116.10	Crest	2.99
Vars	33.01	THD Rms	1.52
Peak W	460.41	THD Fund	1.52
Phase	25° lead	HRMS	1.82
Total PF	0.61	KFactor	0.71
DPF	0.90		17.79



Computer Monitor
Model - Apple M2943
Ratings - 120V, 90W

Low Voltage Condition

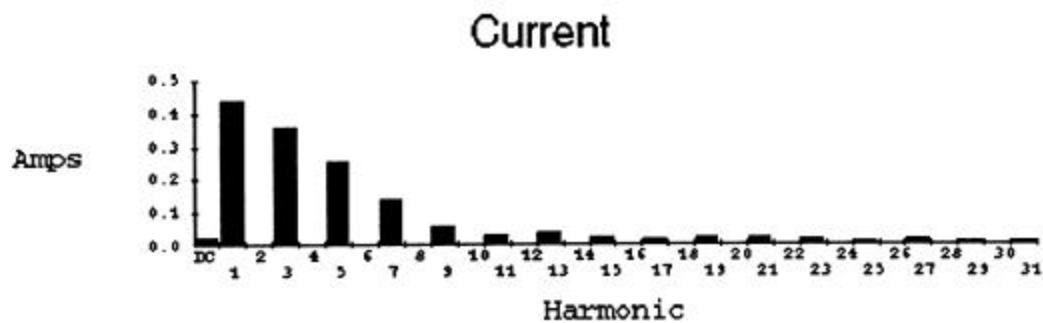
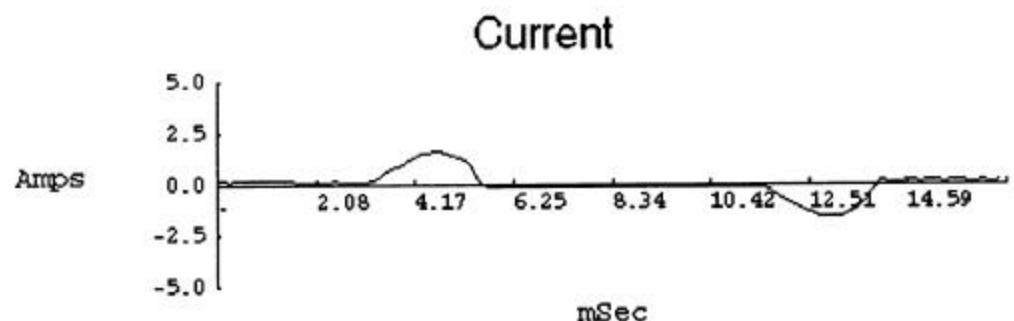
		Voltage	Current
Frequency	59.98	RMS	108.25
Power		Peak	151.69
Watts	71.07	DC Offset	0.12
VA	119.10	Crest	1.4
Vars	36.01	THD Rms	1.39
Peak W	468.41	THD Fund	1.39
Phase	27° lead	HRMS	1.51
Total PF	0.60	KFactor	17.69
DPF	0.89		



Computer Monitor
Model - IBM Aptiva S76
Ratings - 120V

Normal Voltage Condition

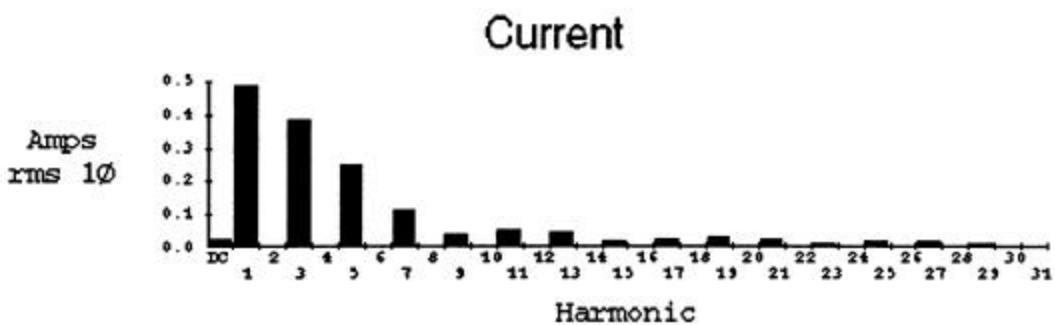
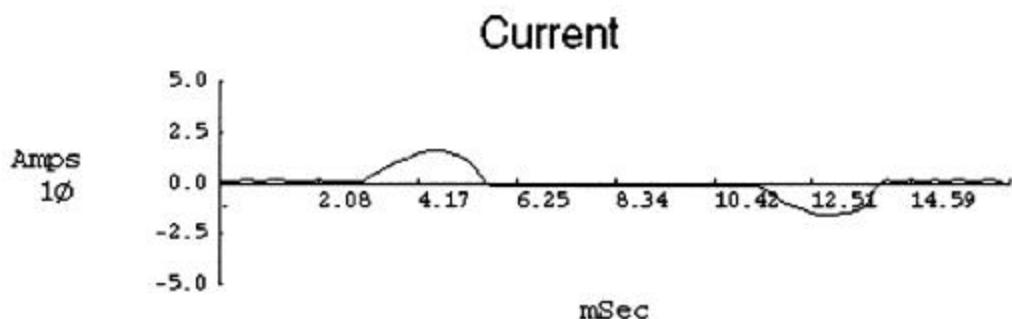
		Voltage	Current
Frequency	59.96	RMS	119.79
Power		Peak	165.65
Watts	51.00	DC Offset	-0.09
VA	77.00	Crest	1.38
Vars	10.00	THD Rms	3.29
Peak W	276.00	THD Fund	3.30
Phase	11° lead	HRMS	3.95
Total PF	0.66	KFactor	13.72
DPF	0.98		



Computer Monitor
Model - IBM Aptiva S76
Ratings - 120V

Low Voltage Condition

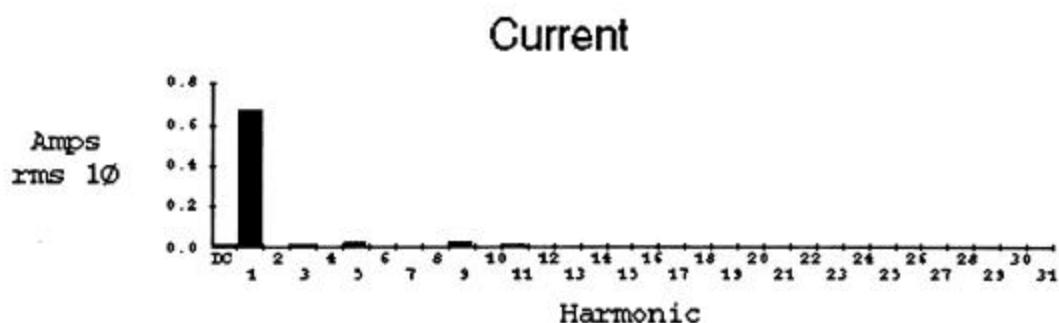
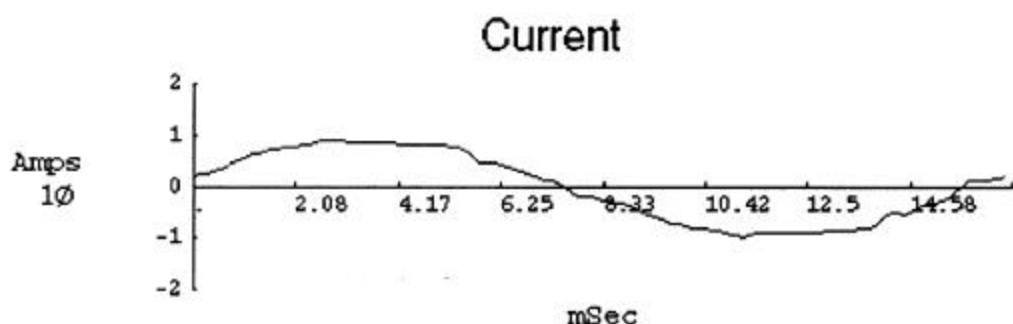
		Voltage	Current
Frequency	59.96	RMS	107.91
Power		Peak	149.31
Watts	51.00	DC Offset	-0.08
VA	74.00	Crest	1.38
Vars	10.00	THD Rms	3.32
Peak W	248.00	THD Fund	3.32
Phase	11° lead	HRMS	3.58
Total PF	0.69	KFactor	0.48
DPF	0.98		11.77



Computer Monitor
Model - Dell Optiplex
Ratings - 120V

Normal Voltage Condition

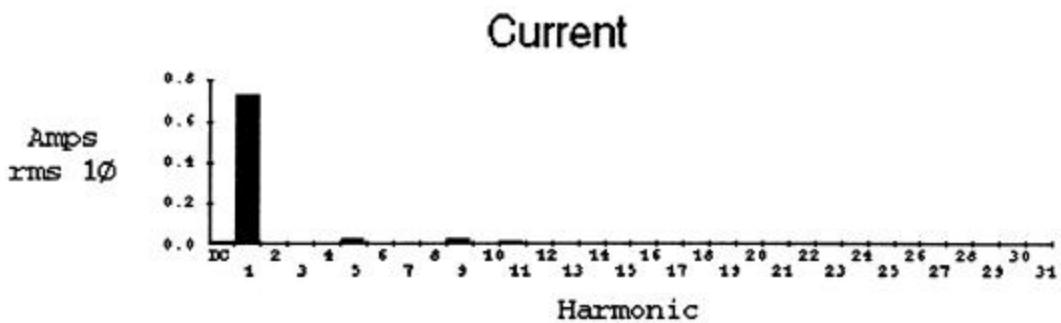
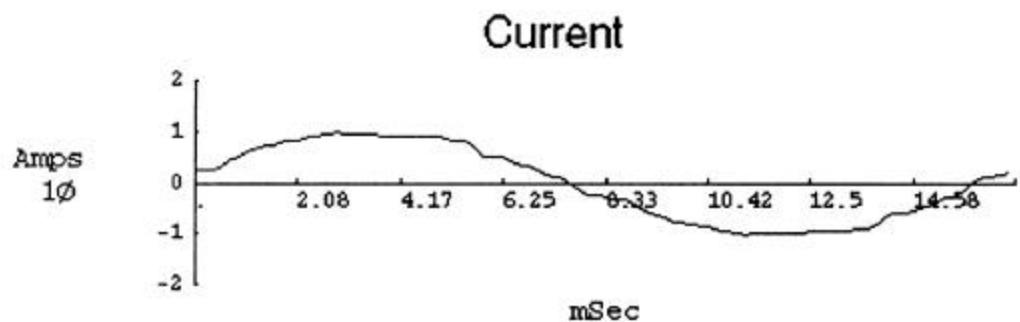
		Voltage	Current
Frequency	60.00	RMS	119.43
Power		Peak	161.43
Watts	77.00	DC Offset	0.10
VA	80.00	Crest	1.35
Vars	23.00	THD Rms	3.99
Peak W	149.00	THD Fund	3.99
Phase	17° lead	HRMS	4.76
Total PF	0.96	KFactor	0.05
DPF	0.96		1.70



Computer Monitor
Model - Dell Optiplex
Ratings - 120V

Low Voltage Condition

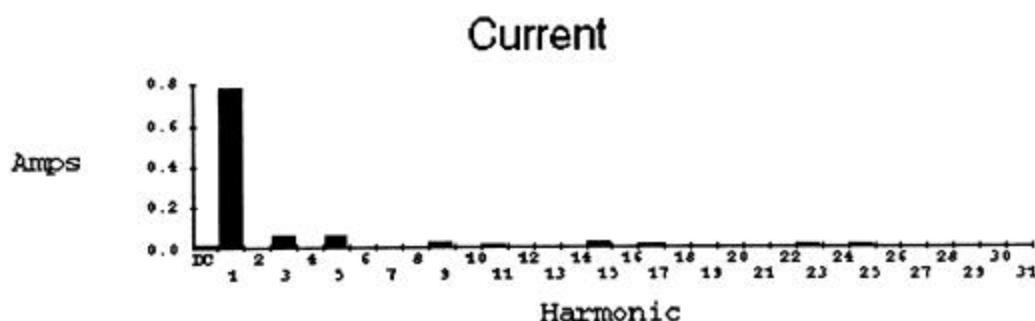
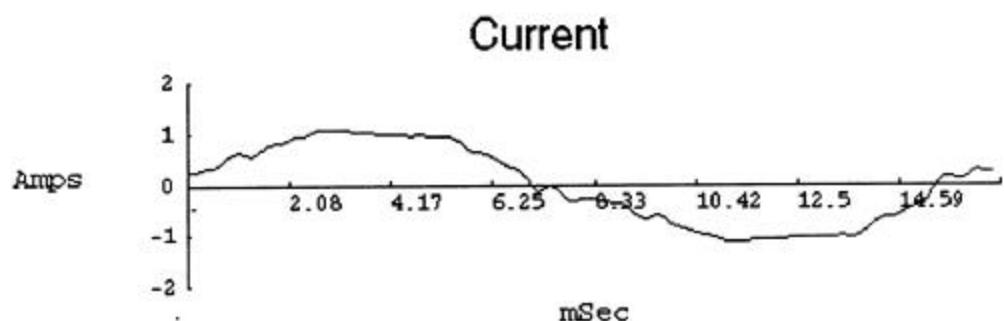
		Voltage	Current
Frequency	60.00	RMS	108.03
Power		Peak	145.99
Watts	75.00	DC Offset	0.05
VA	78.00	Crest	1.35
Vars	19.00	THD Rms	4.00
Peak W	145.00	THD Fund	4.00
Phase	15° lead	HRMS	4.32
Total PF	0.97	KFactor	0.04
DPF	0.97		1.59



Computer Monitor
Model - Sun UltraSPARC
Ratings - 120V

Normal Voltage Condition

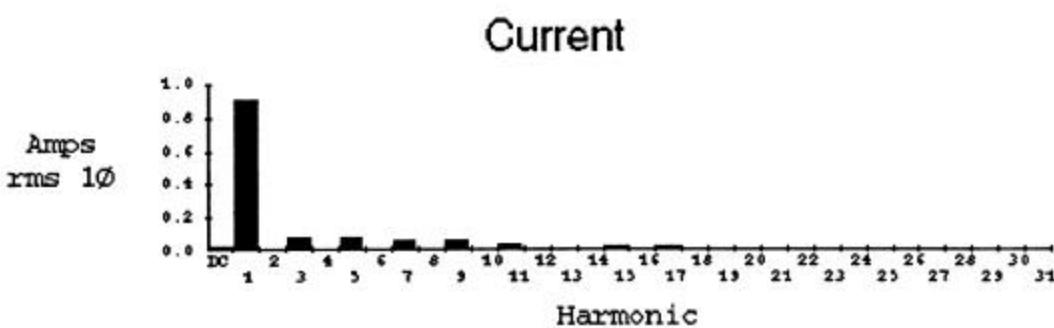
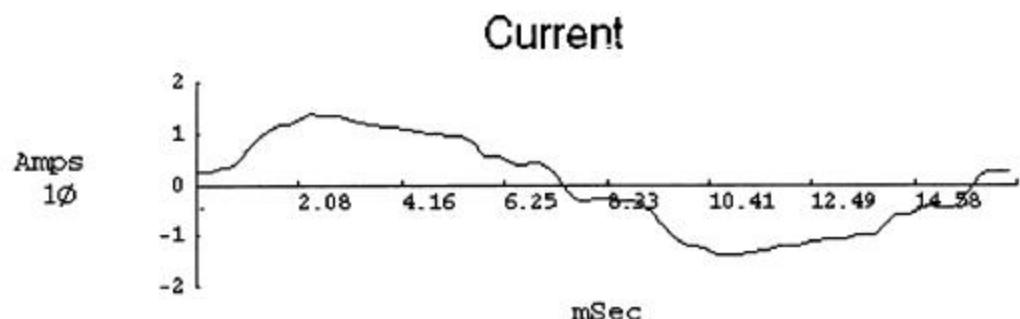
		Voltage	Current
Frequency	60.03	RMS	106.30
Power		Peak	143.80
Watts	92.28	DC Offset	0.03
VA	97.33	Crest	1.35
Vars	30.03	THD Rms	4.05
Peak W	187.57	THD Fund	4.06
Phase	18° lead	HRMS	4.31
Total PF	0.94	KFactor	2.37
DPF	0.95		



Computer Monitor
Model - Sun UltraSPARC
Ratings - 120V

Low Voltage Condition

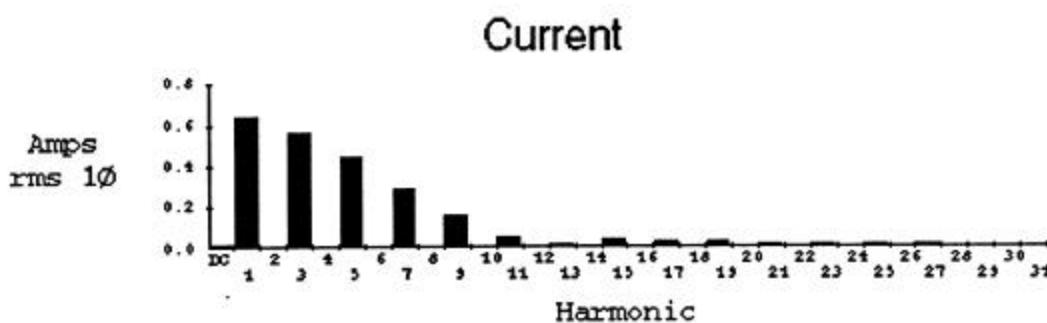
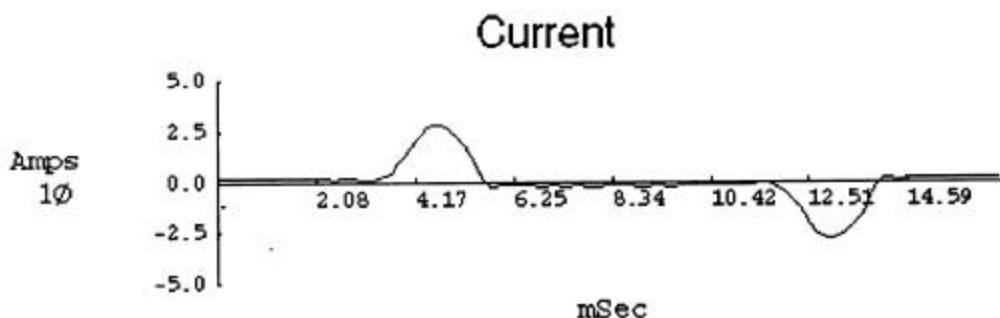
		Voltage	Current
Frequency	60.03	RMS	106.30
Power		Peak	143.80
Watts	92.28	DC Offset	0.03
VA	97.33	Crest	1.35
Vars	30.03	THD Rms	4.05
Peak W	187.57	THD Fund	4.06
Phase	18° lead	HRMS	4.31
Total PF	0.94	KFactor	0.14
DPF	0.95		2.37



Computer Monitor
Model - HP A1497A
Ratings - 120V

Normal Voltage Condition

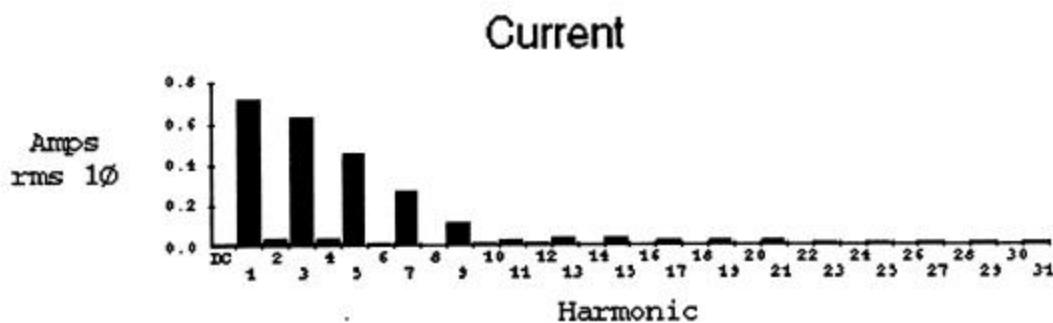
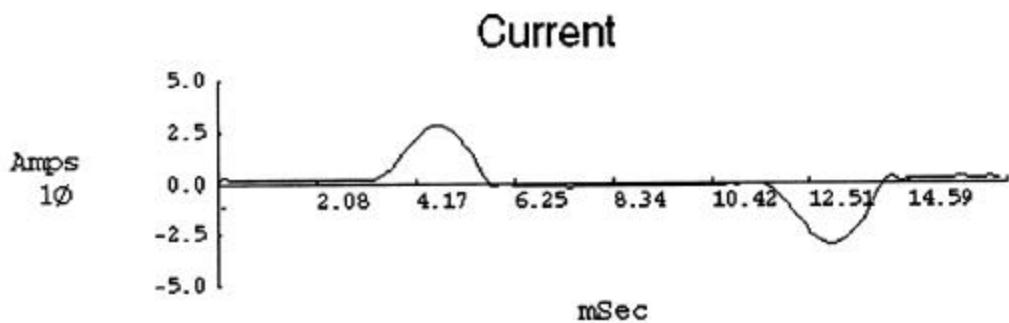
		Voltage	Current
Frequency	59.96	RMS	119.98
Power		Peak	165.61
KW	0.08	DC Offset	-0.06
KVA	0.12	Crest	1.38
KVAR	0.00	THD Rms	3.24
Peak KW	0.48	THD Fund	3.24
Phase	4° lead	HRMS	3.89
Total PF	0.62	KFactor	15.39
DPF	1.00		



Computer Monitor
Model - HP A1497A
Ratings - 120V

Low Voltage Condition

		Voltage	Current
Frequency	59.96	RMS	107.66
Power		Peak	148.81
KW	0.08	DC Offset	0.07
KVA	0.12	Crest	1.38
KVAR	0.00	THD Rms	3.34
Peak KW	0.46	THD Fund	3.34
Phase	4° lead	HRMS	3.60
Total PF	0.65	KFactor	12.93
DPF	1.00		

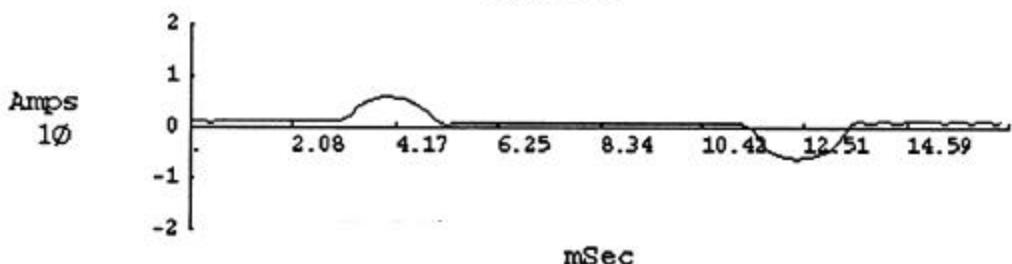


Scanner
Model - Apple Color One 600/27
Ratings - 120V, 35W

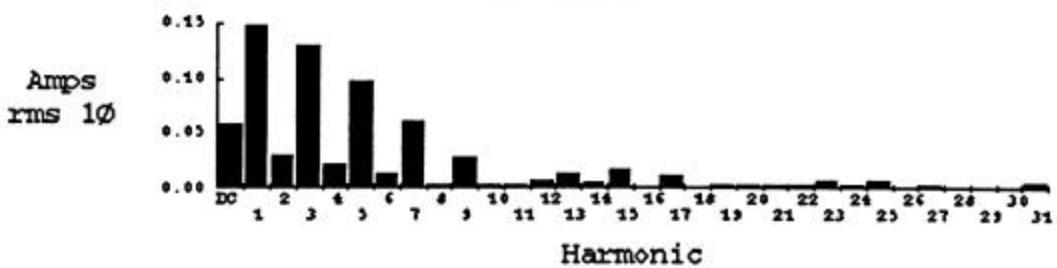
Normal Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	120.04
Power		Peak	167.84
Watts	17.06	DC Offset	0.33
VA	29.10	Crest	1.4
Vars	1.01	THD Rms	1.45
Peak W	107.41	THD Fund	1.45
Phase	7° lead	HRMS	1.74
Total PF	0.61	KFactor	16.66
DPF	0.99		

Current



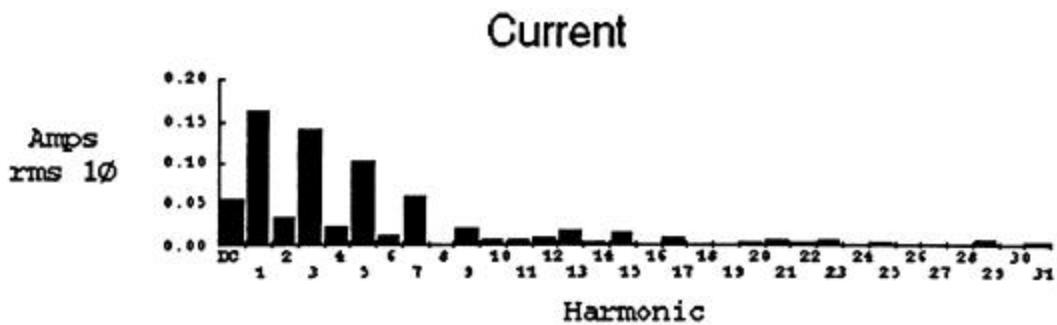
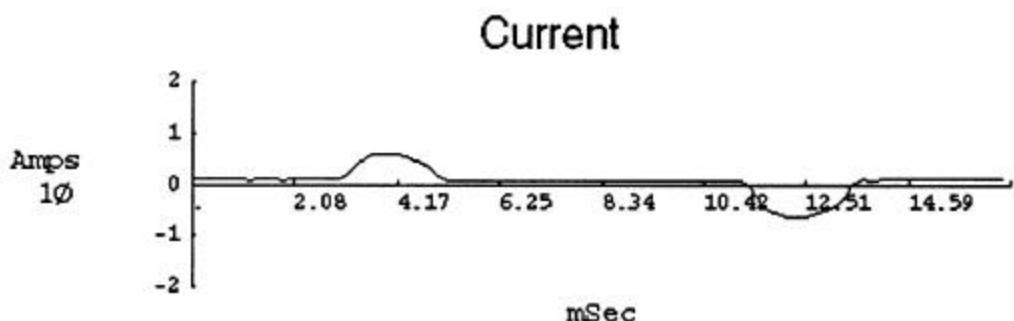
Current



Scanner
Model - Apple Color One 600/27
Ratings - 120V, 35W

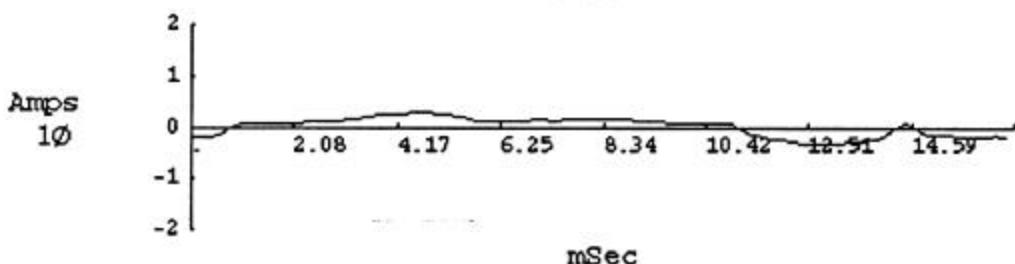
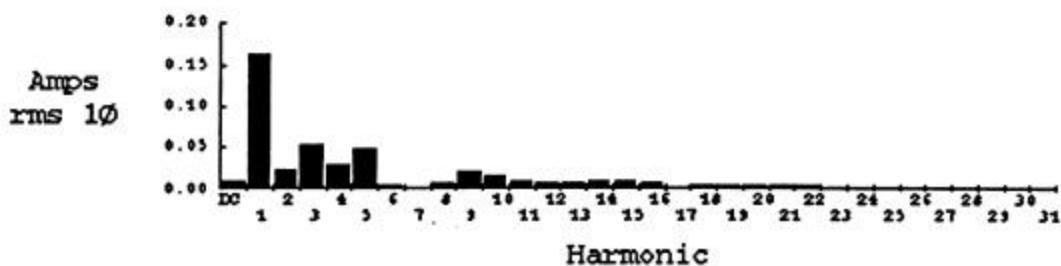
Low Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	108.22
Power		Peak	151.36
Watts	17.06	DC Offset	0.30
VA	27.10	Crest	1.4
Vars	1.01	THD Rms	1.45
Peak W	99.41	THD Fund	1.45
Phase	7° lead	HRMS	1.57
Total PF	0.62	KFactor	15.25
DPF	0.99		



Printer**Model - Apple Color Style Writer 2500****Ratings - 120V, 20W****Normal Voltage Condition**

		Voltage	Current
Frequency	59.98	RMS	120.06
Power		Peak	168.42
Watts	16.06	DC Offset	0.15
VA	22.10	Crest	1.4
Vars	9.01	THD Rms	1.44
Peak W	59.41	THD Fund	1.44
Phase	31° lag	HRMS	1.73
Total PF	0.74	KFactor	9.32
DPF	0.86		

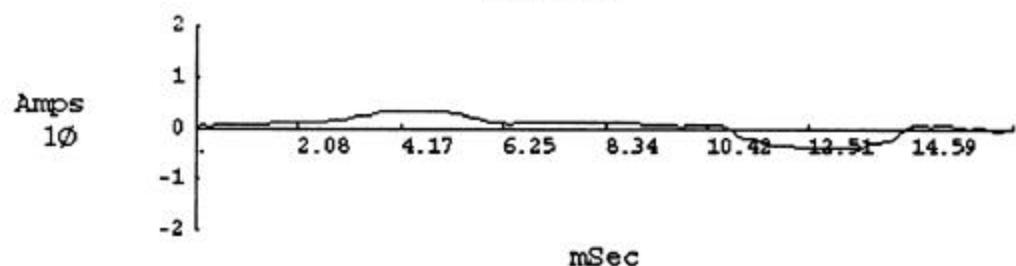
Current**Current**

Printer
Model - Apple Color Style Writer 2500
Ratings - 120V, 20W

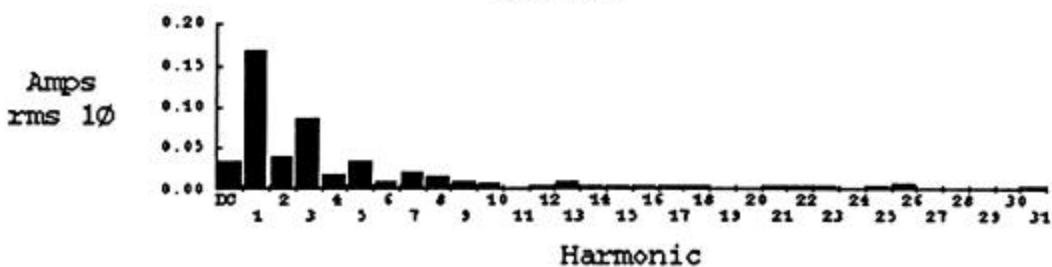
Low Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	107.64
Power		Peak	150.91
Watts	17.06	DC Offset	0.23
VA	21.10	Crest	1.4
Vars	3.01	THD Rms	1.45
Peak W	60.41	THD Fund	1.45
Phase	10° lag	HRMS	1.56
Total PF	0.81	KFactor	8.05
DPF	0.99		

Current



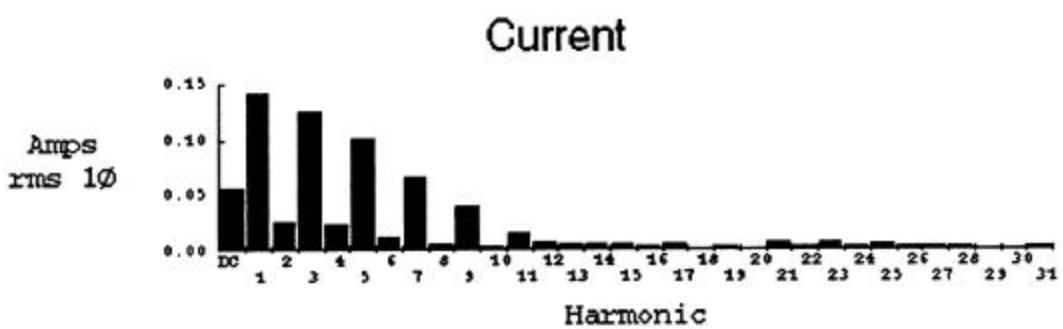
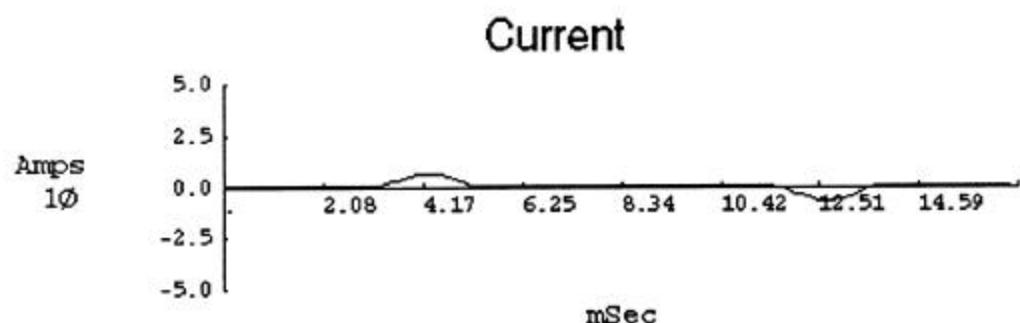
Current



Printer
Model - HP DeskJet722C
Ratings - 120V

Normal Voltage Condition

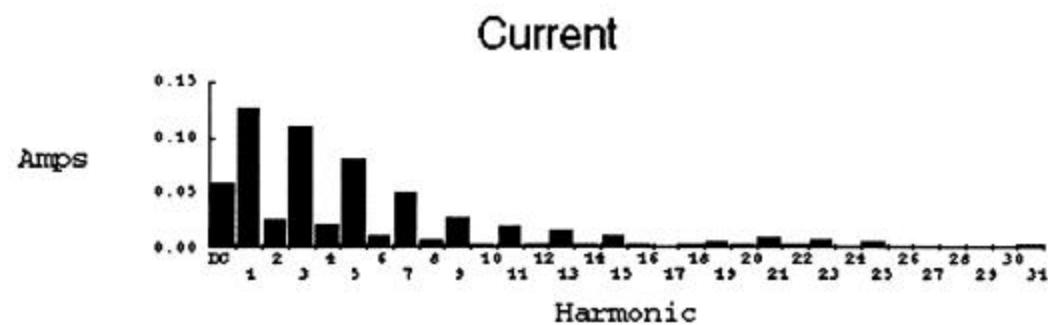
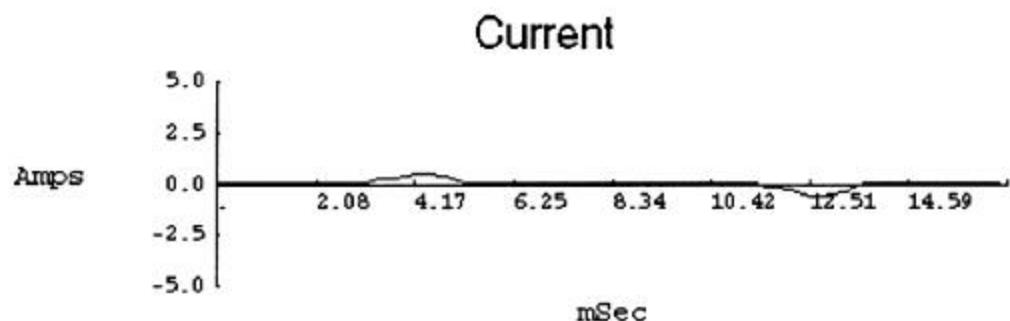
		Voltage	Current
Frequency	59.96	RMS	120.24
Power		Peak	166.71
Watts	16.00	DC Offset	0.22
VA	30.00	Crest	2.73
Vars	1.00	THD Rms	3.28
Peak W	119.00	THD Fund	3.28
Phase	6° lead	HRMS	3.94
Total PF	0.54	KFactor	0.18
DPF	0.99		17.58



Printer
Model - HP DeskJet722C
Ratings - 120V

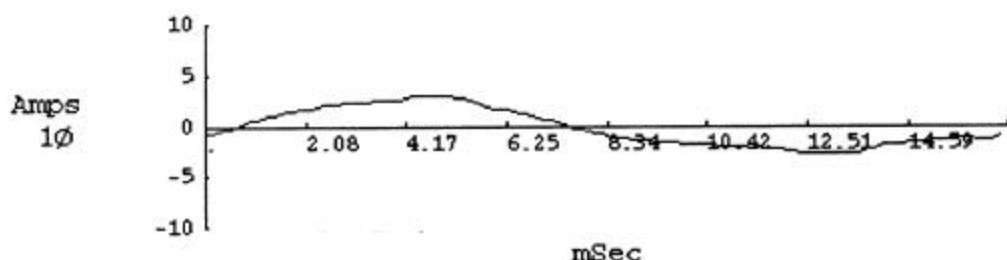
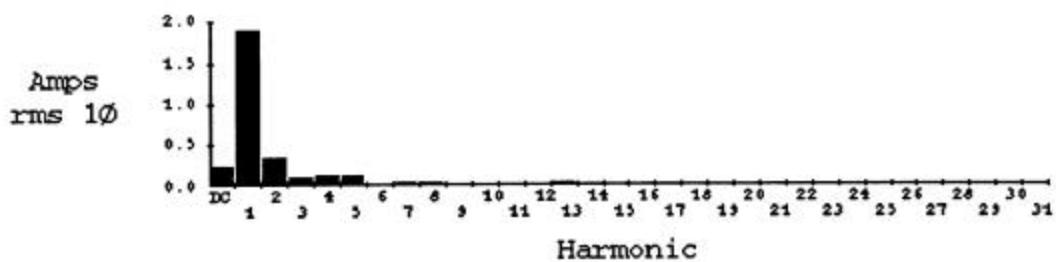
Low Voltage Condition

		Voltage	Current
Frequency	59.96	RMS	0.24
Power		Peak	0.59
Watts	13.00	DC Offset	0.06
VA	25.00	Crest	2.49
Vars	1.00	THD Rms	77.66
Peak W	91.00	THD Fund	123.25
Phase	6° lead	HRMS	0.15
Total PF	0.52	KFactor	18.08
DPF	0.99		



Printer**Model - HF C3155A****Ratings - 120V, 2.5A****Normal Voltage Condition**

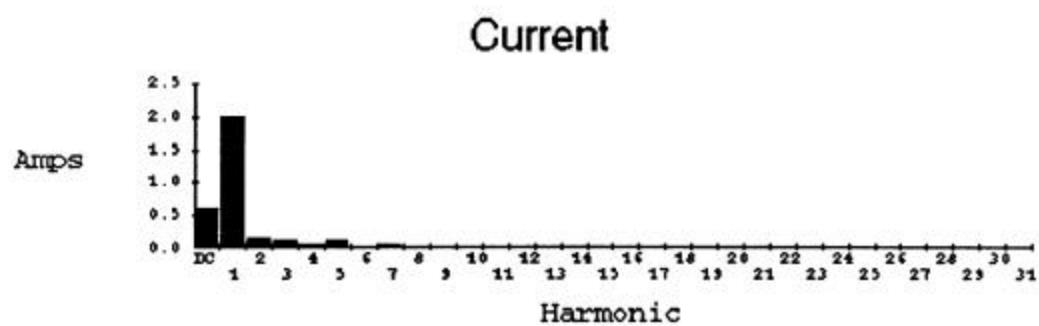
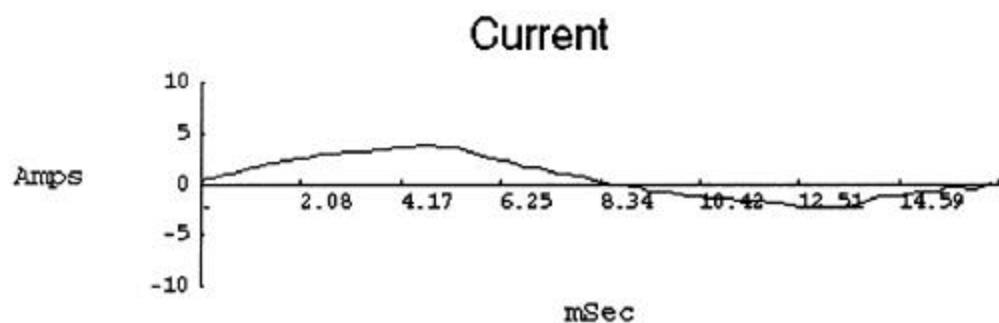
		Voltage	Current
Frequency	59.96	RMS	119.45
Power		Peak	163.70
KW	0.22	DC Offset	-0.44
KVA	0.29	Crest	1.37
KVAR	0.01	THD Rms	3.81
Peak KW	0.50	THD Fund	3.81
Phase	2° lead	HRMS	4.55
Total PF	0.77	KFactor	1.50
DPF	1.00		

Current**Current**

Printer
Model - HP C3155A
Ratings - 120V, 2.5A

Low Voltage Condition

		Voltage	Current
Frequency	59.96	RMS	108.28
Power		Peak	148.49
KW	0.21	DC Offset	-0.20
KVA	0.27	Crest	1.37
KVAR	0.00	THD Rms	3.82
Peak KW	0.58	THD Fund	3.82
Phase	1° lead	HRMS	4.13
Total PF	0.80	KFactor	1.38
DPF	1.00		

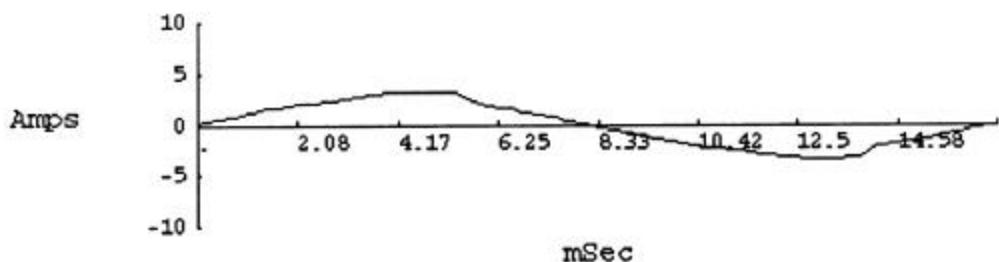


Printer
Model - LaserJet 4MP
Ratings - 120V

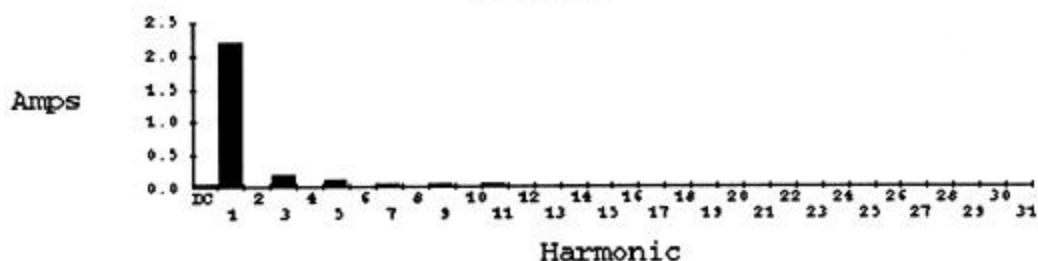
Normal Voltage Condition

		Voltage	Current
Frequency	60.00	RMS	117.75
Power		Peak	159.39
KW	0.26	DC Offset	0.05
KVA	0.31	Crest	1.35
KVAR	0.01	THD Rms	3.98
Peak KW	0.55	THD Fund	10.42
Phase	3° lead	HRMS	4.69
Total PF	0.83	KFactor	1.34
DPF	1.00		

Current



Current



Printer
Model - HP LaserJet 4MP
Ratings - 120V

Low Voltage Condition

		Voltage	Current
Frequency	60.00	RMS	109.41
Power		Peak	148.05
Watts	158.18	DC Offset	0.08
VA	210.26	Crest	1.35
Vars	7.01	THD Rms	3.99
Peak W	364.41	THD Fund	3.99
Phase	3° lead	HRMS	4.36
Total PF	0.76	KFactor	0.25
DPF	1.00		1.80

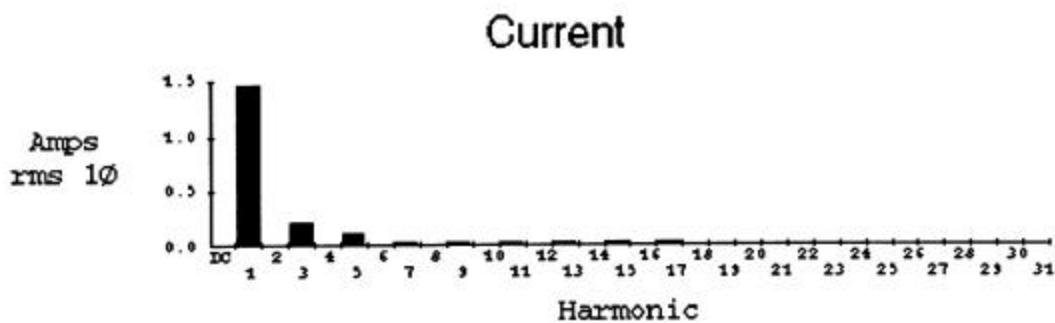
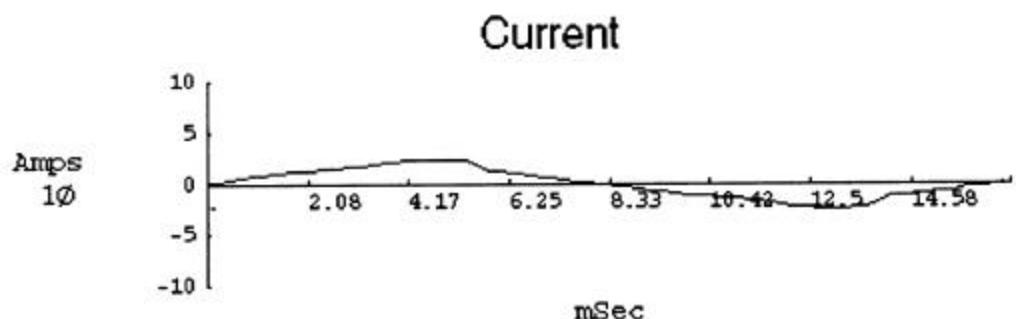


Photo Copier
Model - Canon Copier PC-3II
Ratings 115V, 930W

Phase One
Normal Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	116.38
Power		Peak	163.05
KW	0.92	DC Offset	0.19
KVA	0.92	Crest	1.4
KVAR	0.03	THD Rms	1.44
Peak KW	2.02	THD Fund	1.44
Phase	2° lead	HRMS	1.67
Total PF	1.00	KFactor	0.54
DPF	1.00		1.20

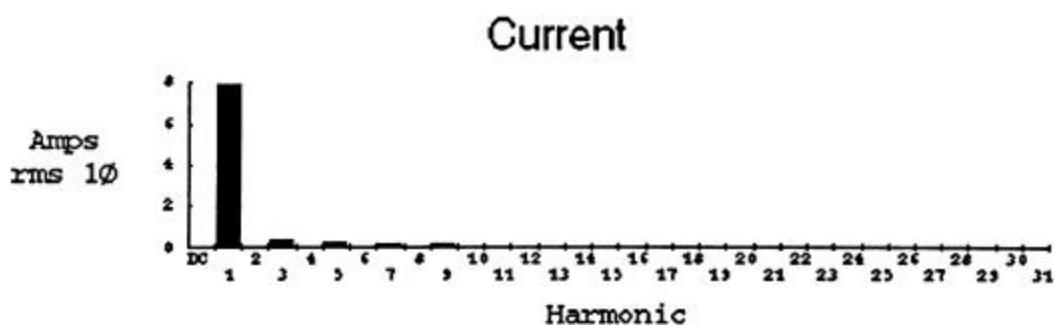
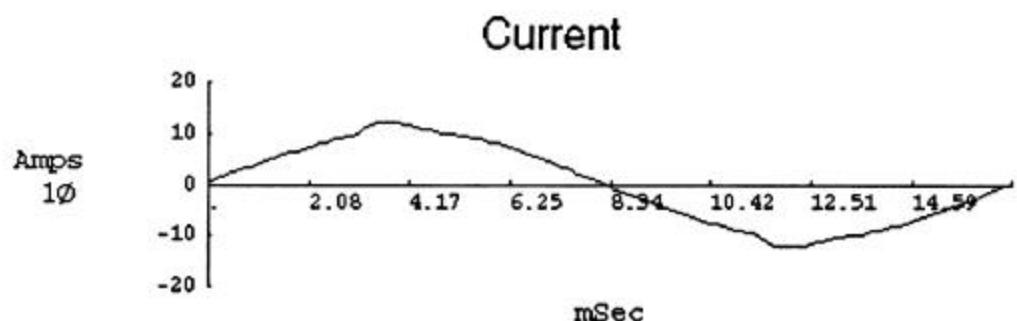


Photo Copier
Model - Canon Copier PC-3II
Ratings 115V, 930W

Phase One
Low Voltage Condition

		Voltage	Current
Frequency	60.05	RMS	104.61
Power		Peak	146.82
KW	0.75	DC Offset	0.06
KVA	0.76	Crest	1.4
KVAR	0.04	THD Rms	1.48
Peak KW	1.71	THD Fund	1.48
Phase	3° lead	HRMS	1.55
Total PF	0.99	KFactor	0.63
DPF	1.00		1.33

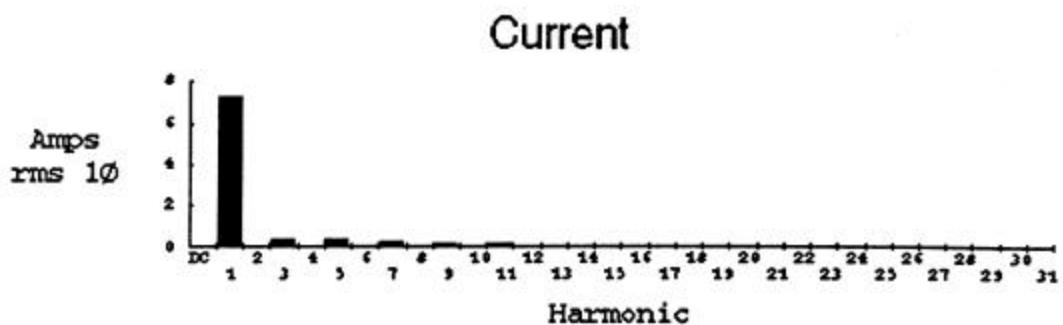
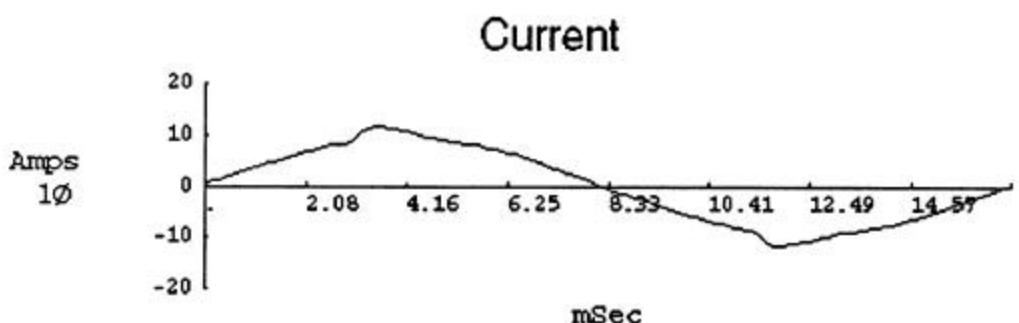


Photo Copier
Model - Canon Copier PC-3II
Ratings 115V, 930W

Phase Two
Normal Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	120.33
Power		Peak	168.53
KW	0.09	DC Offset	0.16
KVA	0.11	Crest	1.4
KVAR	0.01	THD Rms	1.50
Peak KW	0.46	THD Fund	1.50
Phase	6° lead	HRMS	1.80
Total PF	0.79	KFactor	17.72
DPF	0.99		

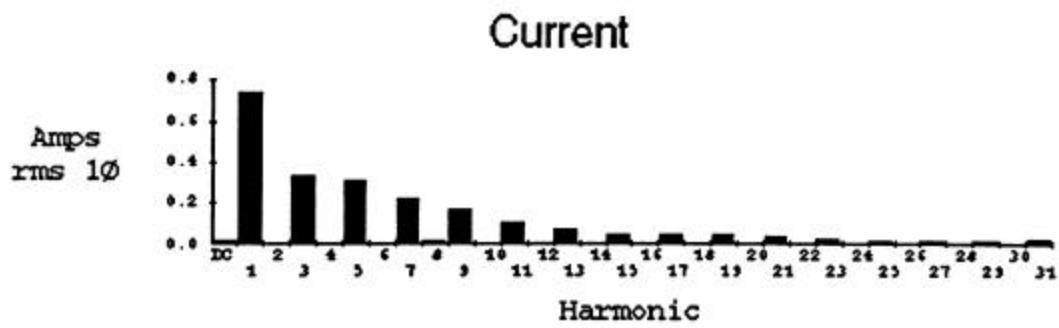
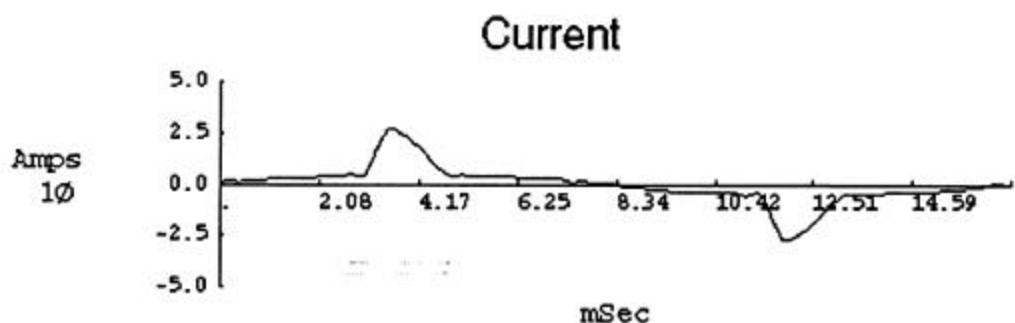
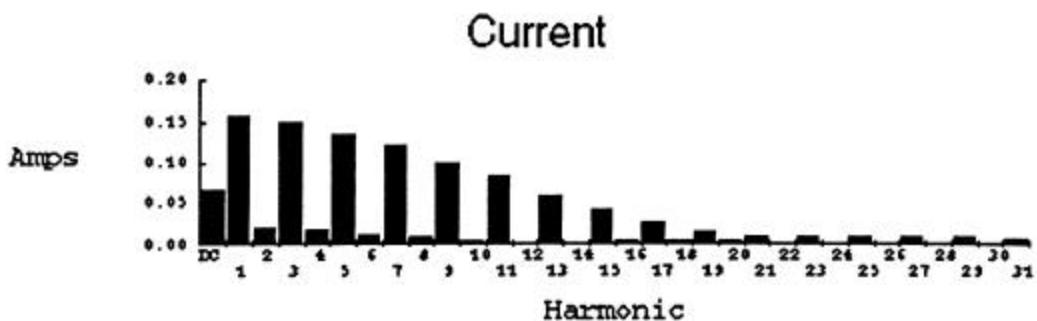
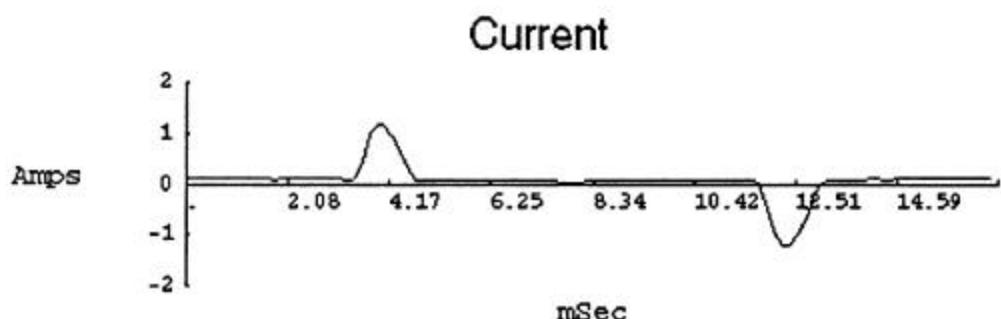


Photo Copier
Model - Canon Copier PC-3II
Ratings 115V, 930W

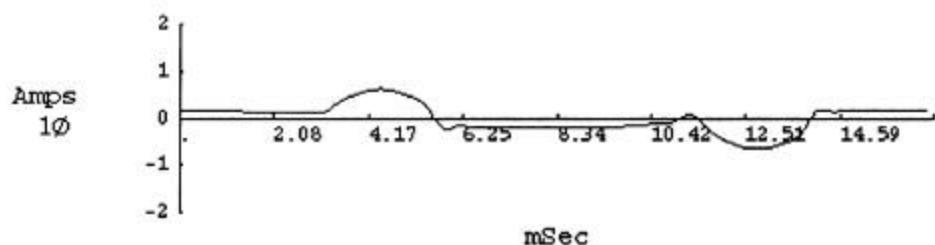
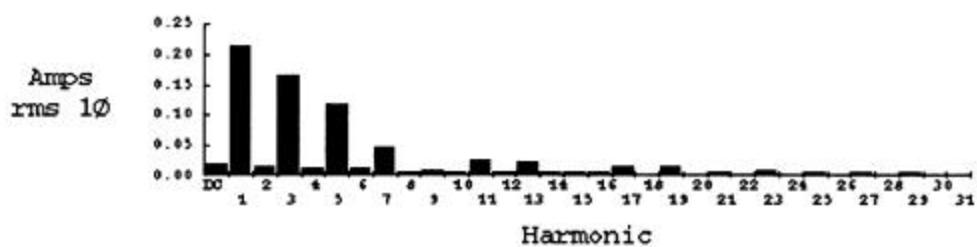
Phase Two
Low Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	108.04
Power		Peak	151.70
Watts	16.75	DC Offset	0.37
VA	35.76	Crest	0.07
Vars	2.04	THD Rms	1.43
Peak W	185.71	THD Fund	1.43
Phase	8° lead	HRMS	180.53
Total PF	0.46	KFactor	0.28
DPF	0.99		**OL**



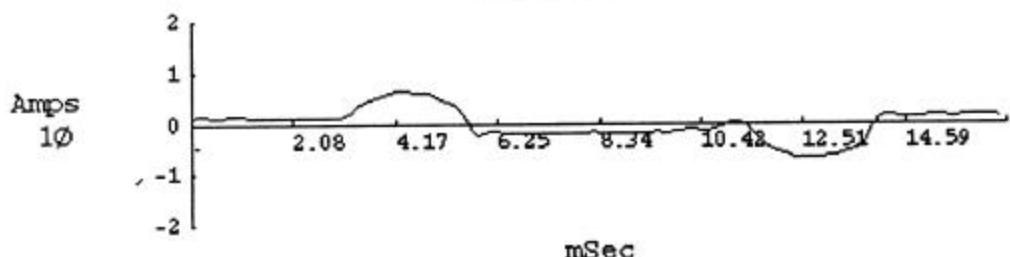
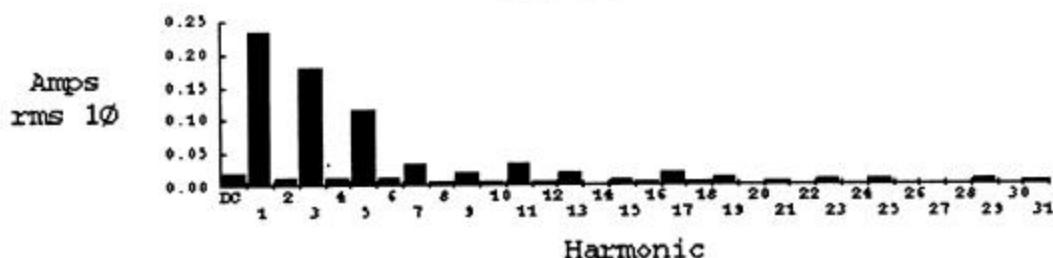
Copier**Model - HP OfficeJet Model 350****Ratings - 120V, 2.5A****Normal Voltage Condition**

		Voltage	Current
Frequency	59.96	RMS	119.81
Power		Peak	164.21
Watts	21.00	DC Offset	0.09
VA	36.00	Crest	1.37
Vars	13.00	THD Rms	3.83
Peak W	109.00	THD Fund	3.83
Phase	31° lead	HRMS	4.59
Total PF	0.59	KFactor	0.21
DPF	0.86		13.13

Current**Current**

Copier**Model - HP OfficeJet Model 350****Ratings - 120V, 2.5A****Low Voltage Condition**

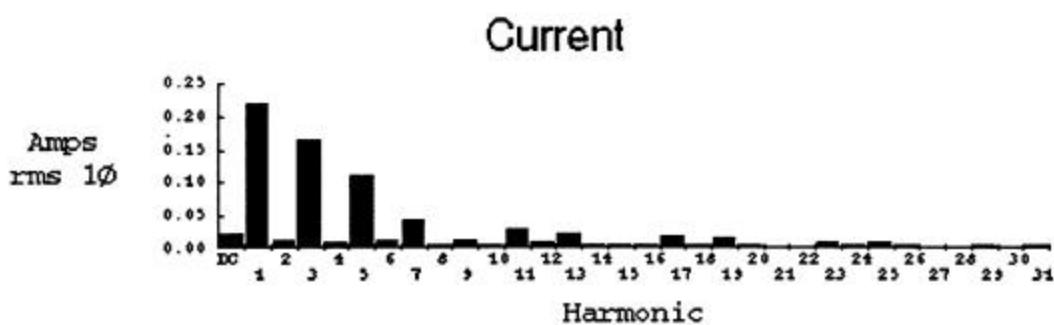
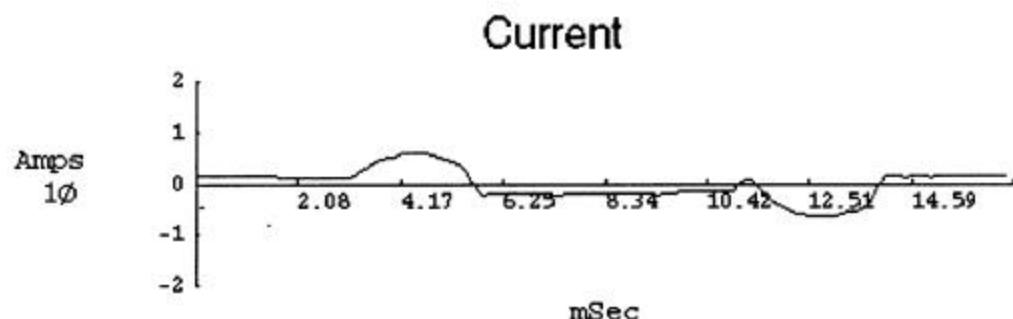
		Voltage	Current
Frequency	59.96	RMS	107.93
Power		Peak	147.90
Watts	22.00	DC Offset	0.00
VA	35.00	Crest	1.37
Vars	11.00	THD Rms	3.90
Peak W	103.00	THD Fund	3.91
Phase	27° lead	HRMS	4.21
Total PF	0.63	KFactor	12.36
DPF	0.89		

Current**Current**

FAX
Model - HP Office 350
Ratings - 120V

Normal Voltage Condition

		Voltage	Current
Frequency	59.96	RMS	119.85
Power		Peak	164.25
Watts	22.00	DC Offset	0.11
VA	36.00	Crest	1.37
Vars	13.00	THD Rms	3.80
Peak W	109.00	THD Fund	3.81
Phase	31° lead	HRMS	4.56
Total PF	0.62	KFactor	13.56
DPF	0.86		

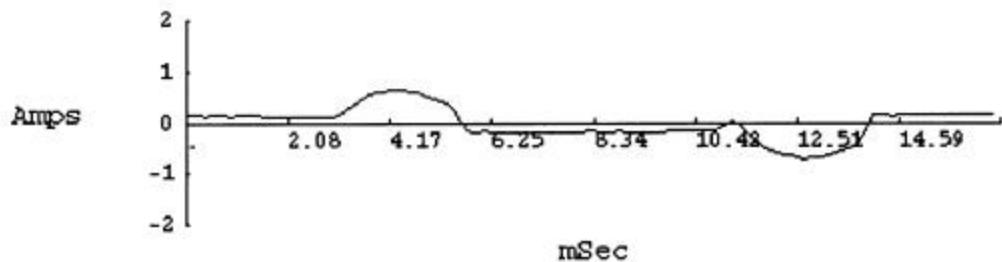


FAX
Model - HP Office 350
Ratings - 120V

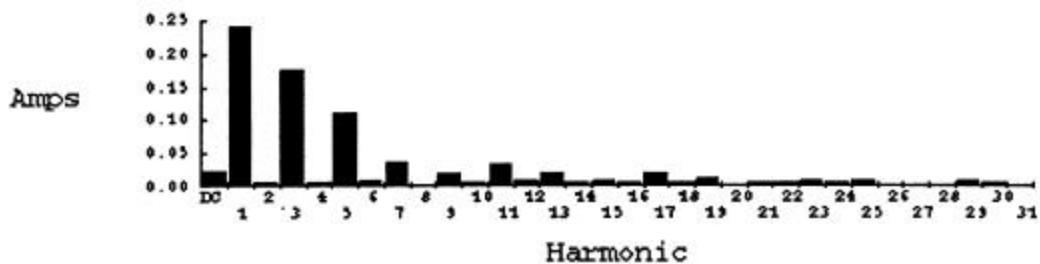
Low Voltage Condition

		Voltage	Current
Frequency	59.96	RMS	107.98
Power		Peak	148.05
Watts	22.00	DC Offset	0.07
VA	35.00	Crest	1.37
Vars	12.00	THD Rms	3.88
Peak W	105.00	THD Fund	3.88
Phase	28° lead	HRMS	4.19
Total PF	0.65	KFactor	12.26
DPF	0.88		

Current



Current

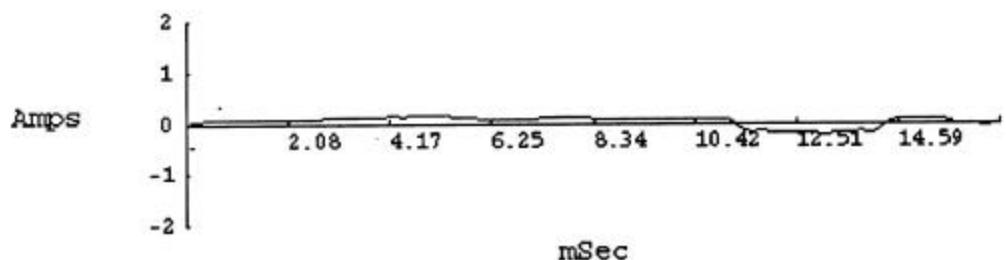


Answering Machine
Model - AT&T Answering System 1309
Ratings - 120V

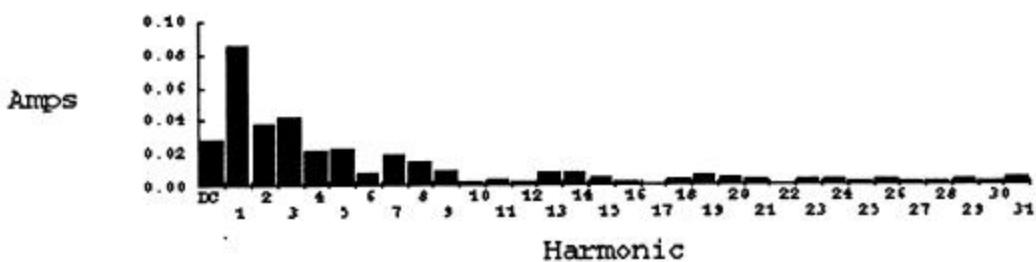
Normal Voltage Condition

		Voltage	Current
Frequency	59.96	RMS	119.84
Power		Peak	167.86
Watts	9.00	DC Offset	0.16
VA	13.00	Crest	1.4
Vars	2.00	THD Rms	2.44
Peak W	37.00	THD Fund	2.44
Phase	16° lag	HRMS	2.92
Total PF	0.71	KFactor	0.07
DPF	0.96		17.02

Current



Current

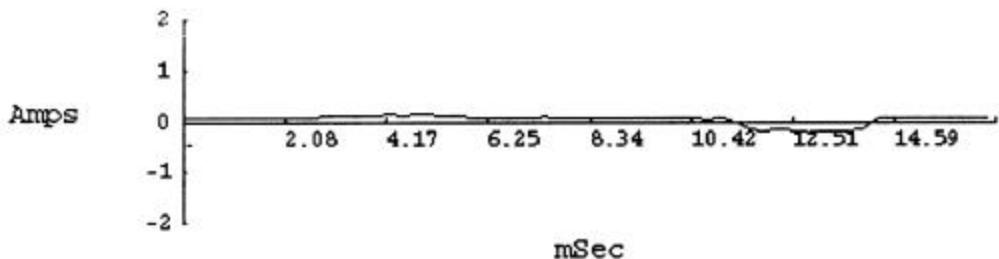


Answering Machine
Model - AT&T Answering System 1309
Ratings - 120V

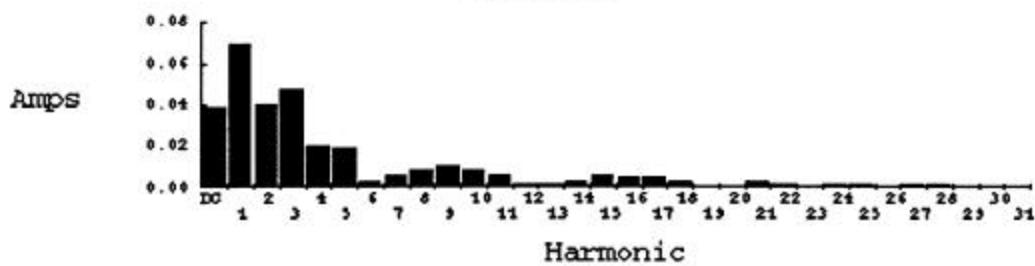
Low Voltage Condition

		Voltage	Current
Frequency	59.96	RMS	107.86
Power		Peak	151.05
Watts	7.00	DC Offset	0.09
VA	11.00	Crest	1.4
Vars	0.00	THD Rms	2.49
Peak W	32.00	THD Fund	2.49
Phase	6° lag	HRMS	2.68
Total PF	0.67	KFactor	11.45
DPF	0.99		

Current



Current

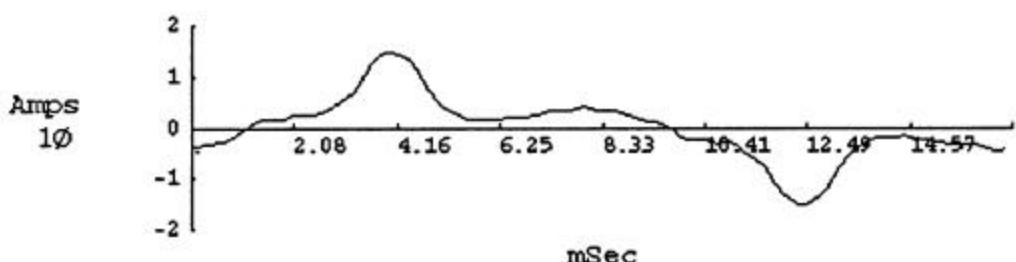


Uninterrupted Power Supply (UPS)
Model - APC Back-UPS Pro 650
Ratings - 120V, 410W, 650VA

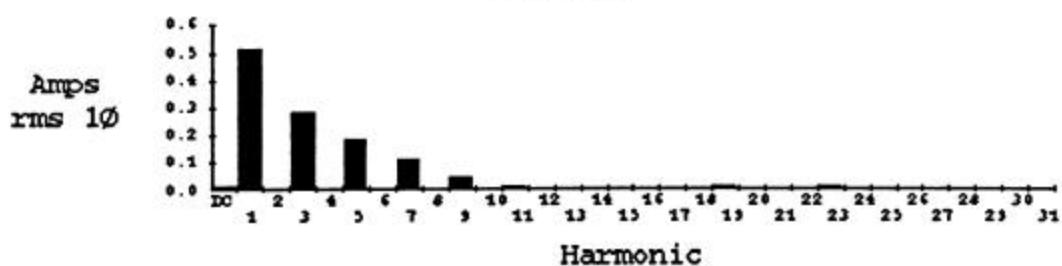
Normal Voltage Condition

		Voltage	Current
Frequency	60.04	RMS	119.97
Power		Peak	167.86
Watts	60.06	DC Offset	0.00
VA	75.10	Crest	1.4
Vars	13.01	THD Rms	1.56
Peak W	259.41	THD Fund	1.56
Phase	13° lag	HRMS	1.88
Total PF	0.80	KFactor	0.35
DPF	0.98		7.21

Current



Current

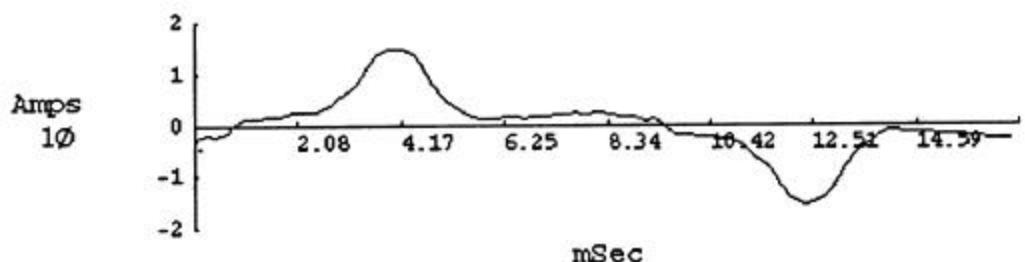


Uninterrupted Power Supply (UPS)
Model - APC Back-UPS Pro 650
Ratings - 120V, 410W, 650VA

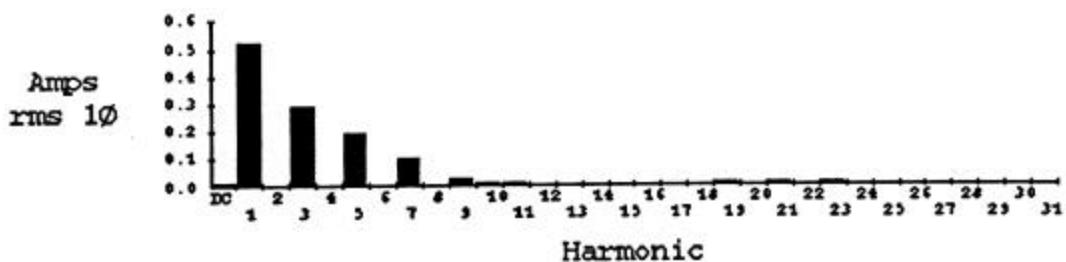
Low Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	108.15
Power		Peak	151.32
Watts	56.06	DC Offset	0.09
VA	69.10	Crest	1.4
Vars	4.01	THD Rms	1.52
Peak W	240.41	THD Fund	1.52
Phase	4° lag	HRMS 1.64	0.36
Total PF	0.81	KFactor	7.00
DPF	1.00		

Current



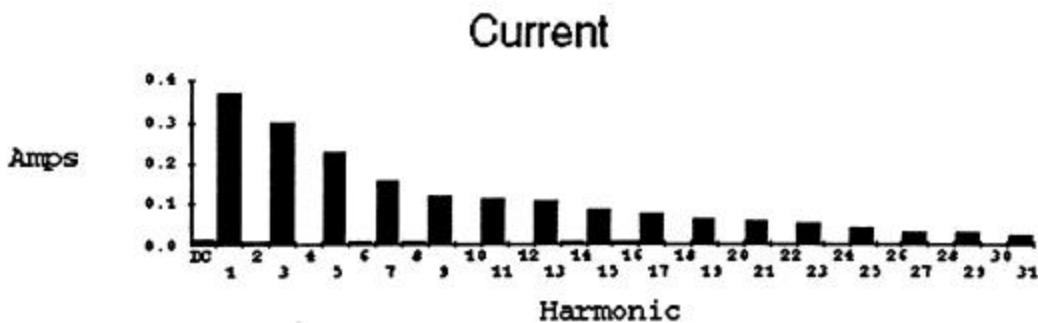
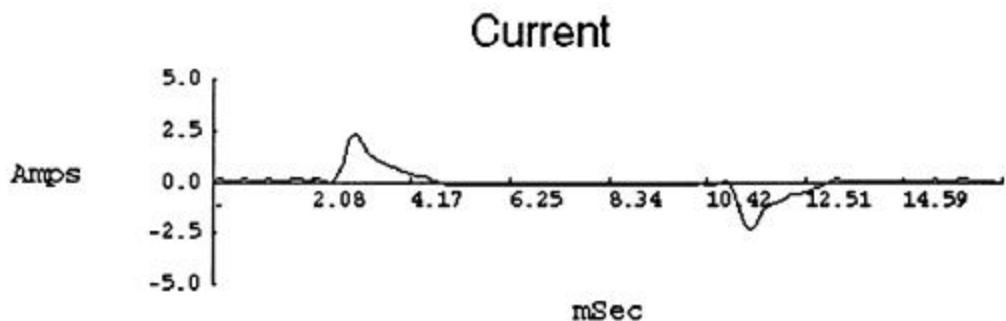
Current



Laptop Battery Recharger
Model - Macintosh Power Book AC Adapter M4402
Ratings - 120V, 45W, 120VA

Normal Voltage Condition

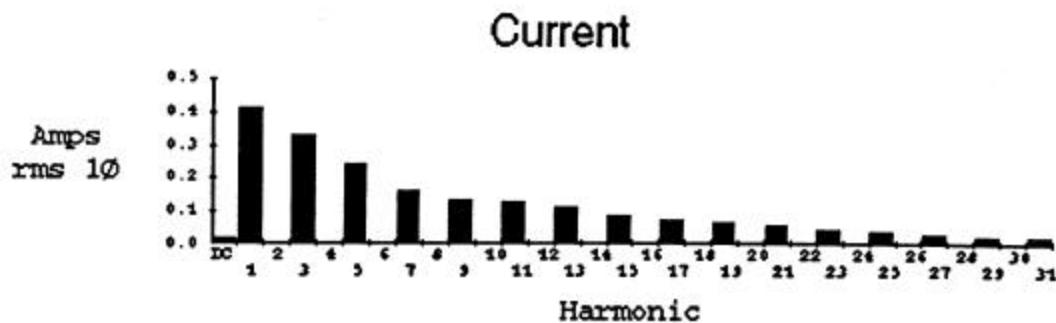
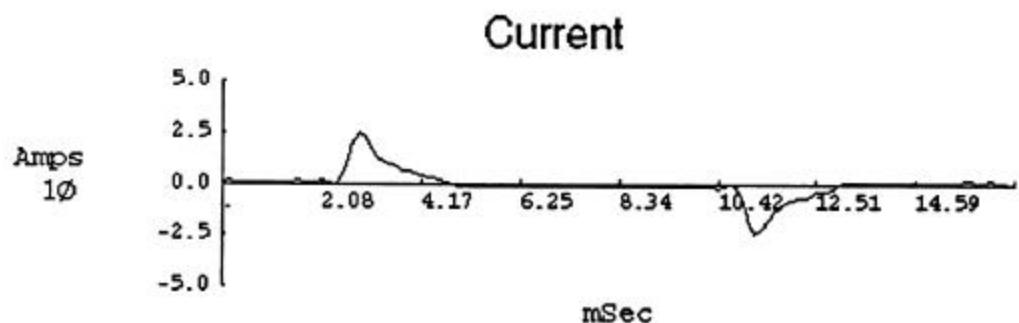
		Voltage	Current
Frequency	59.98	RMS	120.50
Power		Peak	169.41
Watts	35.09	DC Offset	0.09
VA	72.15	Crest	1.41
Vars	26.02	THD Rms	1.31
Peak W	371.59	THD Fund	1.31
Phase	37° lead	HRMS	130.81
Total PF	0.49	KFactor	0.48
DPF	0.80		**OL**



Laptop Battery Recharger
Model - Macintosh Power Book AC Adapter M4402
Ratings - 120V, 45W, 120VA

Low Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	0.66
Power		Peak	2.56
Watts	35.09	DC Offset	-0.02
VA	71.15	Crest	3.87
Vars	26.02	THD Rms	78.22
Peak W	348.59	THD Fund	125.55
Phase	37° lead	HRMS	0.51
Total PF	0.50	KFactor	**OL**
DPF	0.80		





Appendix A.5

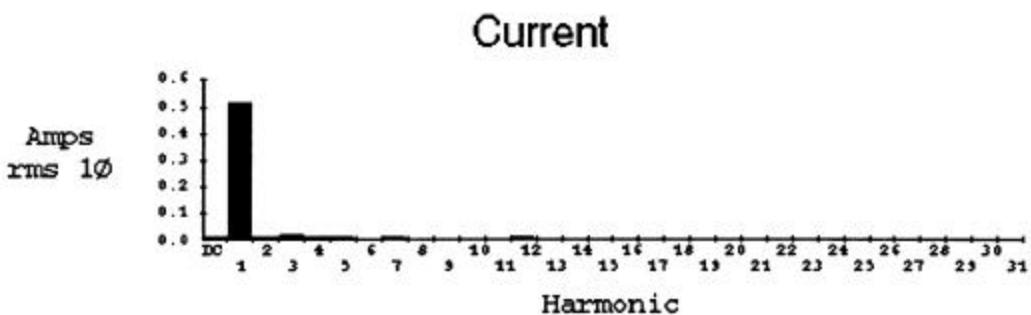
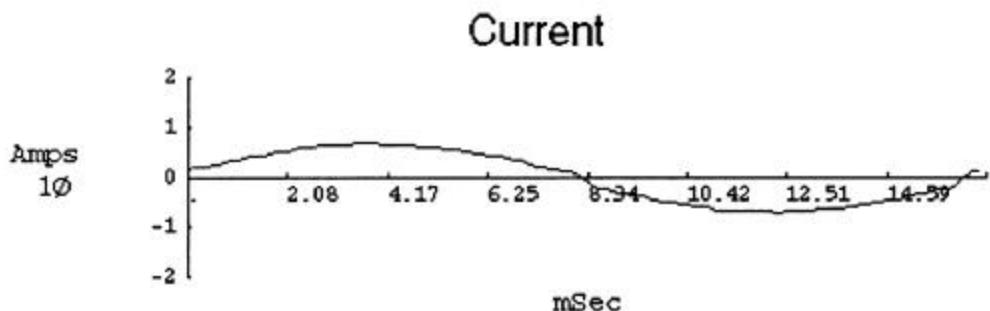
Other Household Appliances



Light Bulb
Model - General Electric
Ratings - 120V, 60W

Normal Voltage Condition

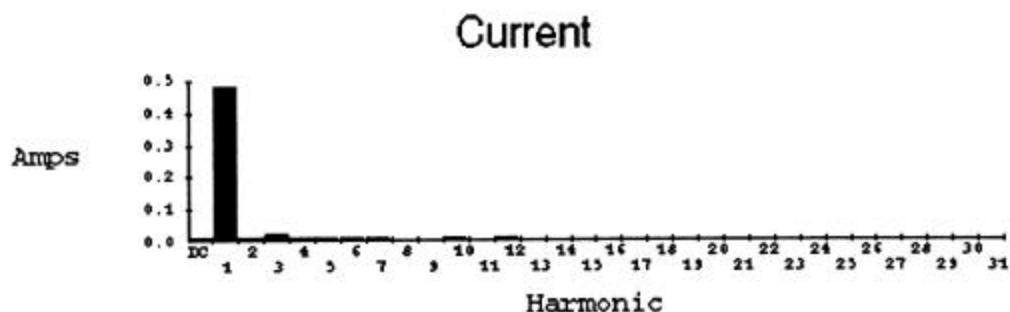
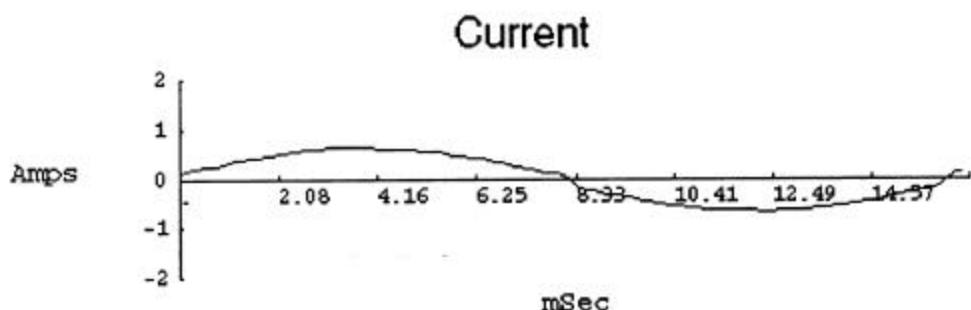
		Voltage	Current
Frequency	59.98	RMS	120.40
Power		Peak	168.91
Watts	60.01	DC Offset	0.16
VA	61.03	Crest	1.4
Vars	7.14	THD Rms	1.41
Peak W	120.28	THD Fund	1.41
Phase	7° lead	HRMS	1.70
Total PF	0.99	KFactor	1.52
DPF	0.99		



Light Bulb
Model - General Electric
Ratings - 120V, 60W

Low Voltage Condition

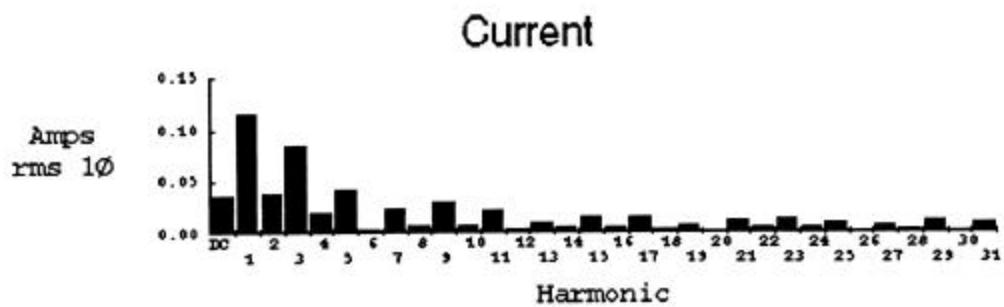
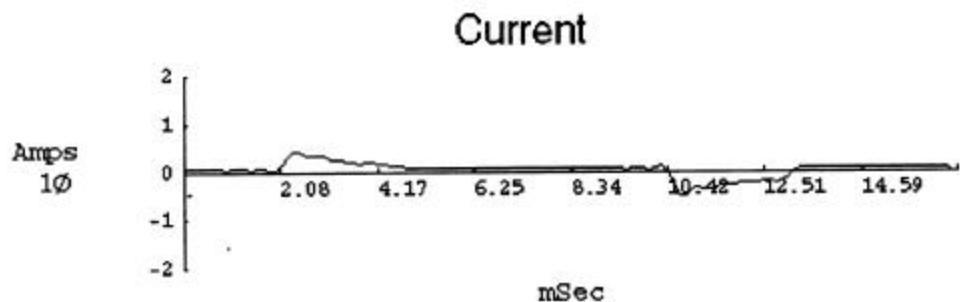
		Voltage	Current
Frequency	60.04	RMS	0.49
Power		Peak	0.67
Watts	52.01	DC Offset	-0.01
VA	52.03	Crest	1.37
Vars	6.14	THD Rms	7.62
Peak W	103.28	THD Fund	7.64
Phase	7° lead	HRMS	0.04
Total PF	0.99	KFactor	1.50
DPF	0.99		



**Compact Fluorescent Bulb
Model - Lights of America 2000
Ratings - 120V, 13W**

Normal Voltage Condition

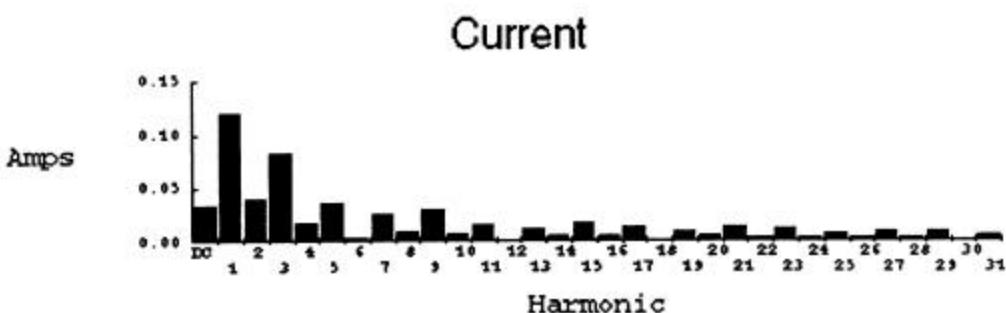
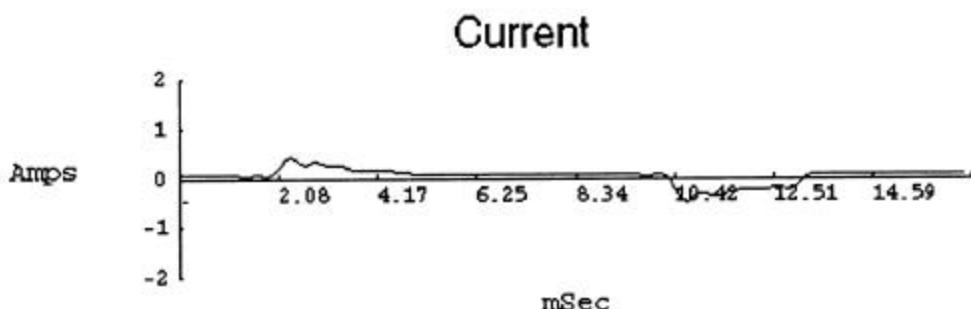
		Voltage	Current
Frequency	59.96	RMS	119.79
Power		Peak	168.40
Watts	12.00	DC Offset	0.21
VA	20.00	Crest	1.41
Vars	5.00	THD Rms	2.36
Peak W	67.00	THD Fund	2.36
Phase	21° lead	HRMS	2.83
Total PF	0.63		0.12
DPF	0.93		



**Compact Fluorescent Bulb
Model - Lights of America 2000
Ratings - 120V, 13W**

Low Voltage Condition

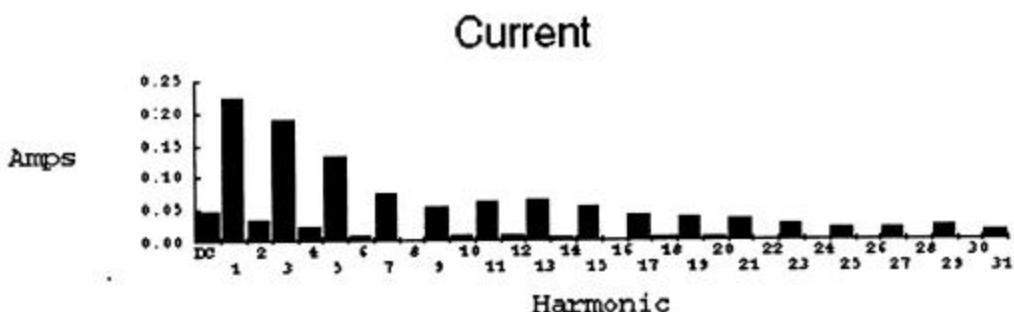
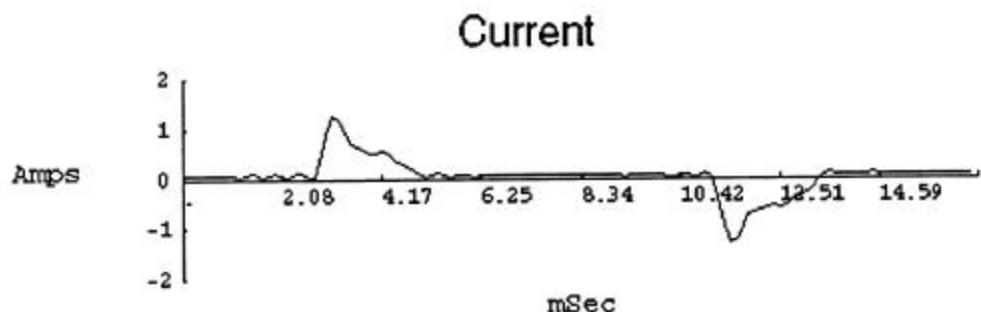
		Voltage	Current
Frequency	59.96	RMS	107.82
Power		Peak	151.70
Watts	11.00	DC Offset	0.18
VA	18.00	Crest	2.75
Vars	4.00	THD Rms	2.38
Peak W	58.00	THD Fund	2.38
Phase	22° lead	HRMS	2.56
Total PF	0.64	KFactor	29.29
DPF	0.93		



**Compact Fluorescent Light
Model - Lights of America 2630
Ratings - 120V, 30W**

Normal Voltage Condition

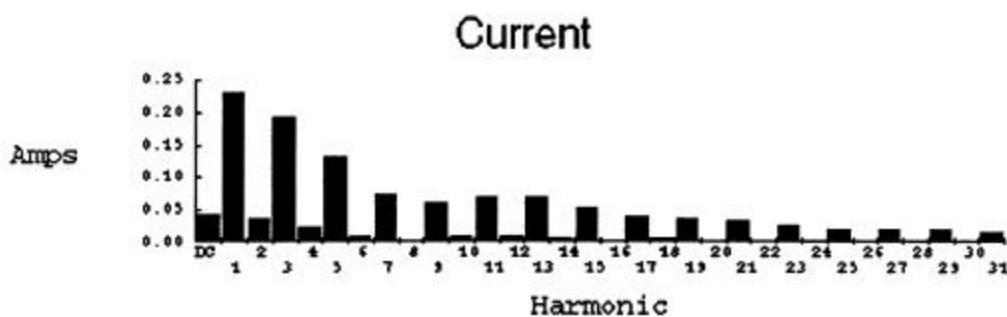
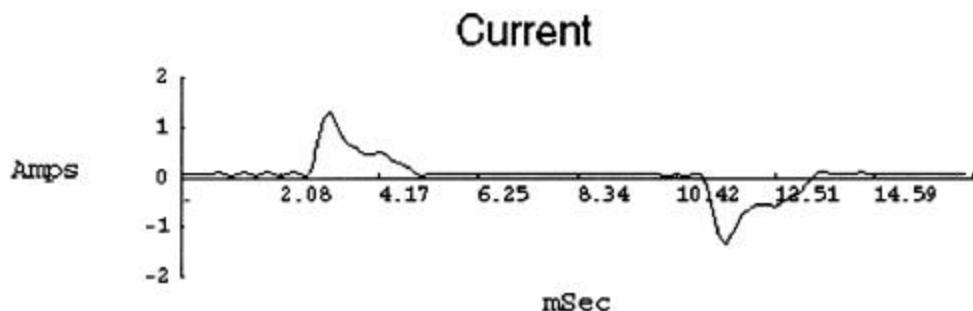
		Voltage	Current
Frequency	59.96	RMS	119.49
Power		Peak	167.95
Watts	25.00	DC Offset	0.30
VA	43.00	Crest	1.41
Vars	5.00	THD Rms	2.54
Peak W	203.00	THD Fund	2.54
Phase	12° lead	HRMS	3.03
Total PF	0.59		0.28
DPF	0.98		



**Compact Fluorescent Light
Model - Lights of America 2630
Ratings - 120V, 30W**

Low Voltage Condition

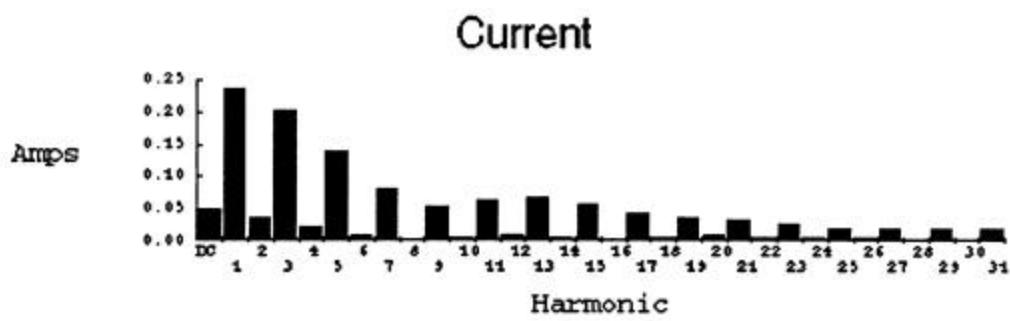
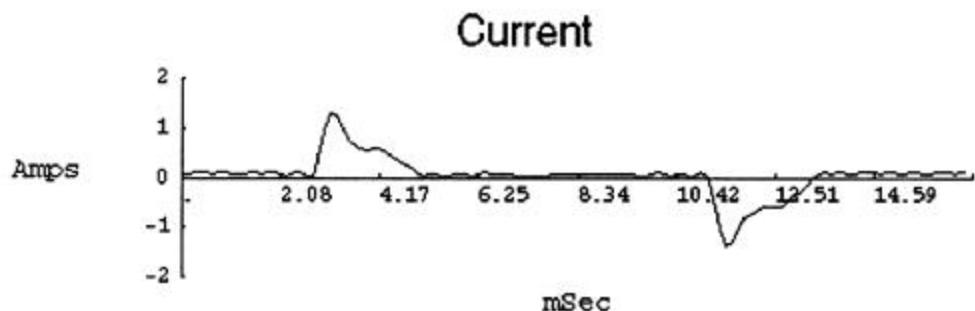
		Voltage	Current
Frequency	59.96	RMS	108.24
Power		Peak	152.34
Watts	23.00	DC Offset	0.27
VA	40.00	Crest	1.41
Vars	5.00	THD Rms	2.55
Peak W	192.00	THD Fund	2.55
Phase	13° lead	HRMS	2.76
Total PF	0.59	DPF	0.98



**Compact Fluorescent Light
Model - Lights of America 4010
Ratings - 120V, 30W**

Normal Voltage Condition

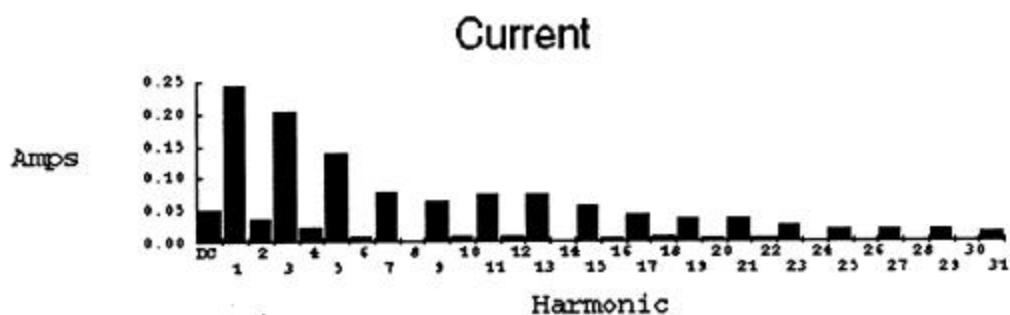
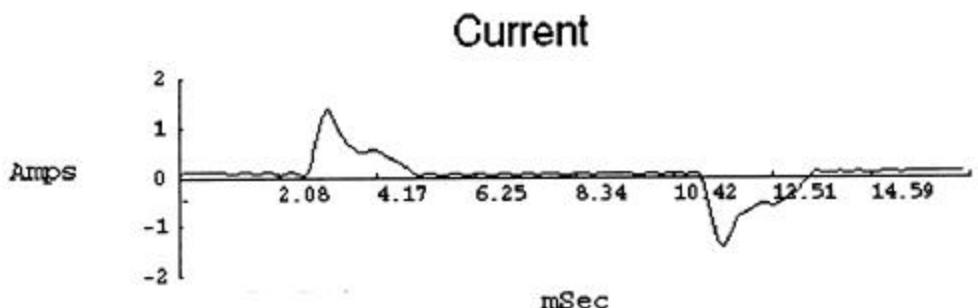
		Voltage	Current
Frequency	59.96	RMS	120.43
Power		Peak	169.38
Watts	27.00	DC Offset	0.15
VA	46.00	Crest	1.41
Vars	7.00	THD Rms	2.59
Peak W	215.00	THD Fund	2.59
Phase	15° lead	HRMS	3.12
Total PF	0.58		0.30
DPF	0.97		



Compact Fluorescent Light
Model - Lights of America 4010
Ratings - 120V, 30W

Low Voltage Condition

		Voltage	Current
Frequency	59.96	RMS	0.40
Power		Peak	1.46
Watts	24.00	DC Offset	0.05
VA	42.00	Crest	3.67
Vars	7.00	THD Rms	78.02
Peak W	203.00	THD Fund	124.71
Phase	16° lead	HRMS	0.31
Total PF	0.58		
DPF	0.96		

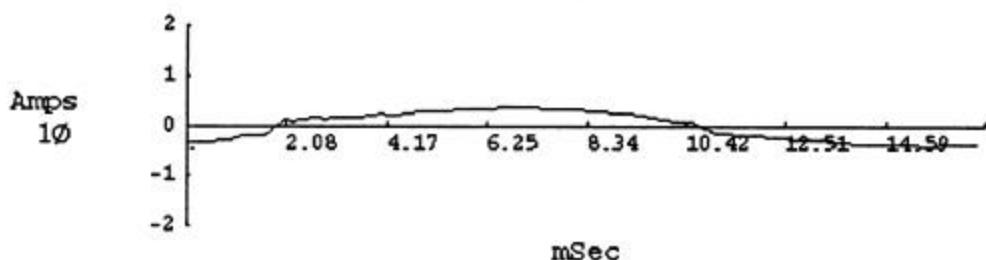


Electronic Ballast
Model - Sylvania CF20EL
Ratings - 120V, 20W

Normal Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	120.19
Power		Peak	168.66
Watts	21.52	DC Offset	0.13
VA	34.58	Crest	1.4
Vars	26.02	THD Rms	1.50
Peak W	53.39	THD Fund	1.50
Phase	51° lag	HRMS	1.80
Total PF	0.63	KFactor	0.04
DPF	0.62		2.40

Current



Current

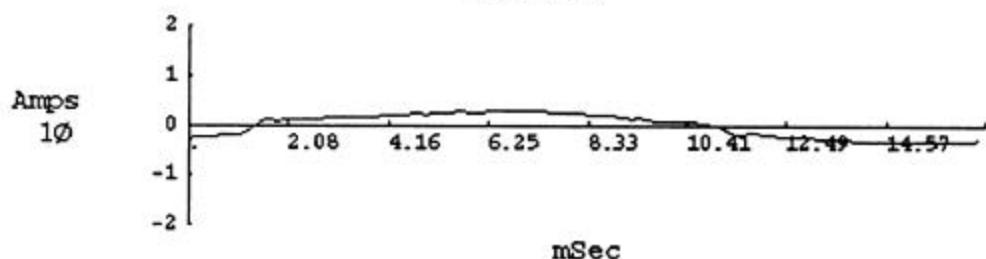


Electronic Ballast
Model - Sylvania CF20EL
Ratings - 120V, 20W

Low Voltage Condition

		Voltage	Current
Frequency	60.04	RMS	108.01
Power		Peak	151.44
Watts	16.52	DC Offset	0.06
VA	24.58	Crest	1.4
Vars	17.02	THD Rms	1.57
Peak W	42.39	THD Fund	1.57
Phase	46° lag	HRMS	1.69
Total PF	0.68	KFactor	0.05
DPF	0.70		3.18

Current



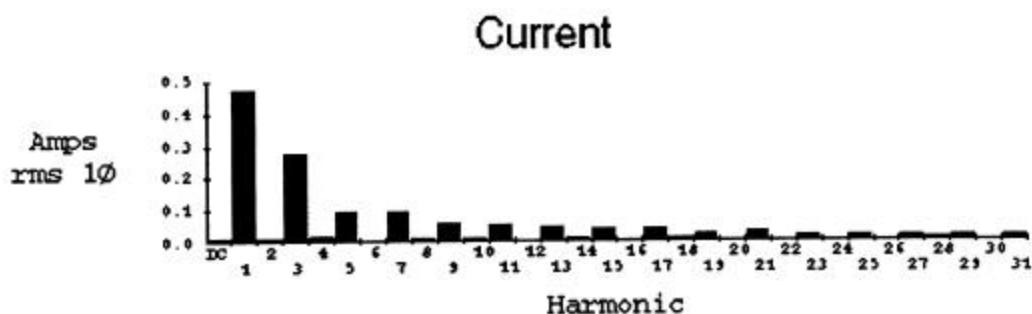
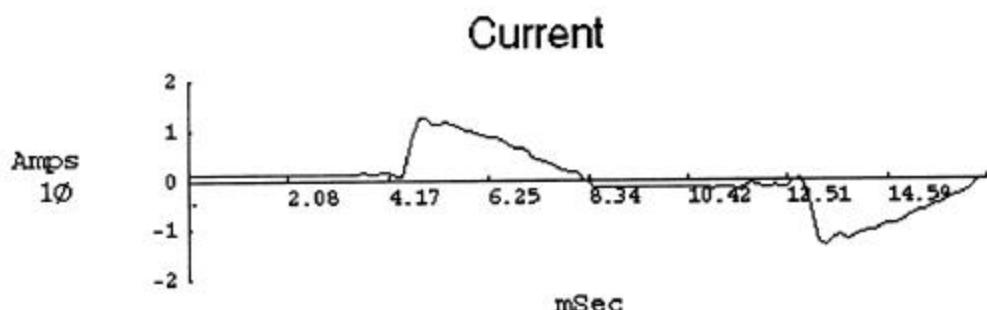
Current



Light Dimmer
Model – Lutron TI-300
Ratings – 120V, 300W

Normal Voltage Condition

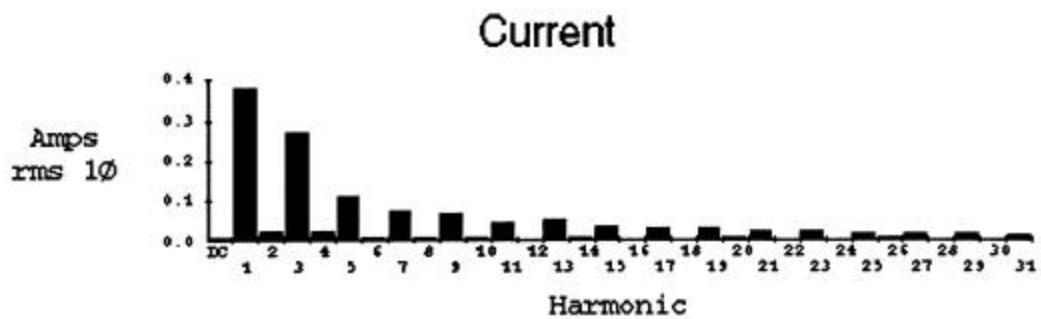
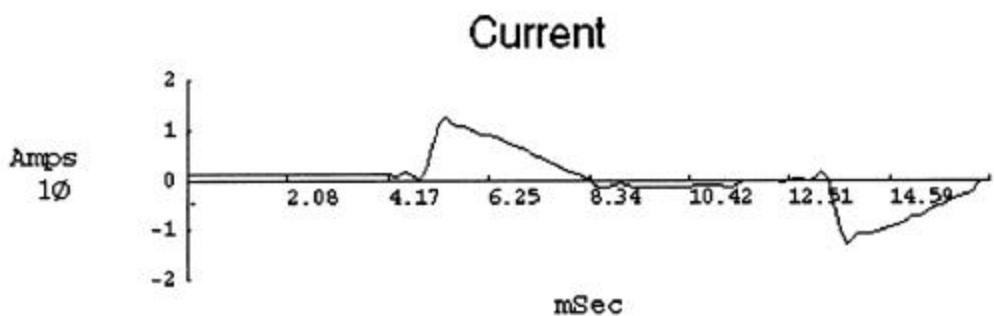
		Voltage	Current
Frequency	59.98	RMS	0.58
Power		Peak	1.34
Watts	50.52	DC Offset	-0.01
VA	69.58	Crest	2.32
Vars	26.02	THD Rms	56.40
Peak W	223.39	THD Fund	68.30
Phase	28° lag	HRMS	0.33
Total PF	0.73	KFactor	14.89
DPF	0.88		



Light Dimmer
Model – Lutron TI-300
Ratings – 120V, 300W

Low Voltage Condition

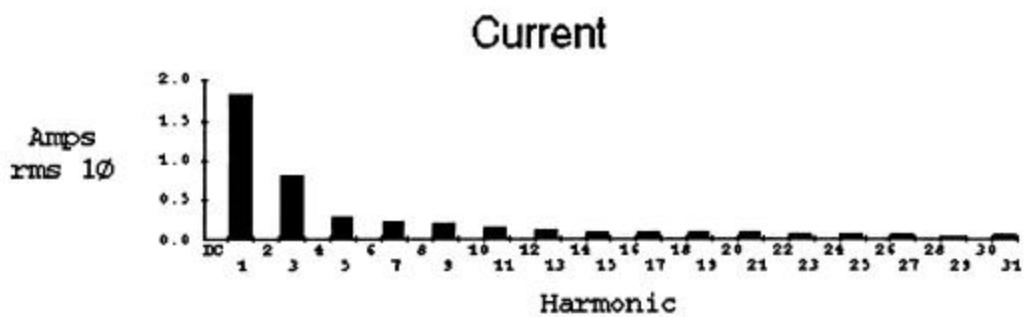
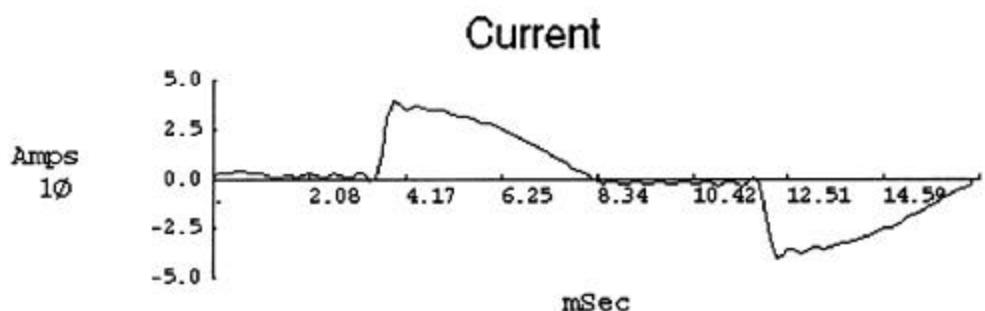
		Voltage	Current
Frequency	59.98	RMS	108.08
Power		Peak	151.79
Watts	34.52	DC Offset	0.14
VA	54.58	Crest	1.4
Vars	22.02	THD Rms	1.36
Peak W	182.39	THD Fund	1.36
Phase	34° lag	HRMS	1.47
Total PF	0.63	KFactor	19.56
DPF	0.83		



Light Dimmer
Model – Lutron 6B38
Ratings – 120V, 600W

Normal Voltage Condition

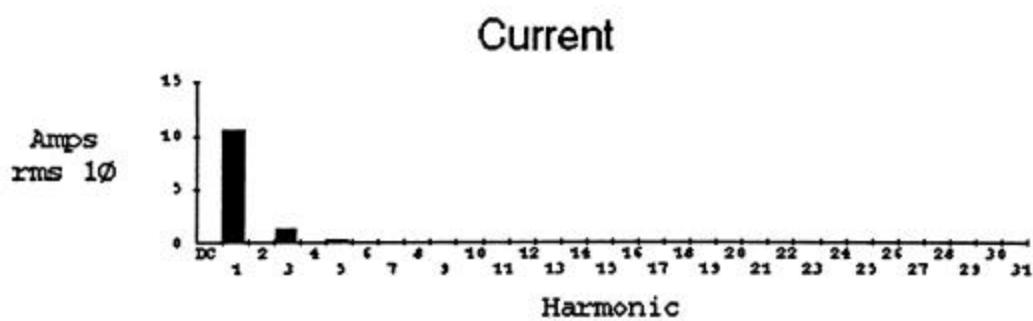
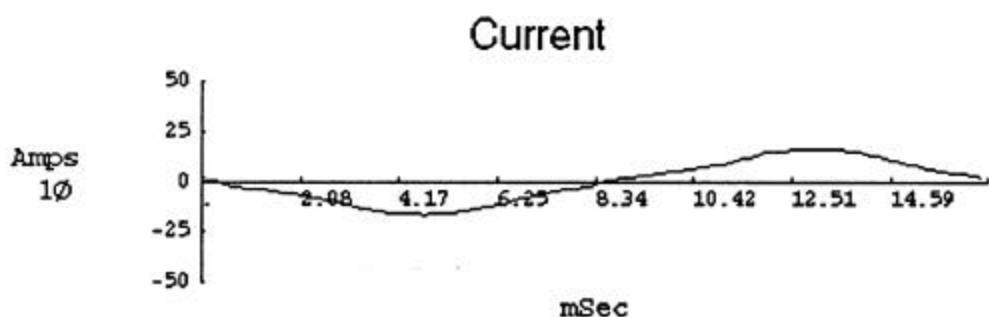
		Voltage	Current
Frequency	59.98	RMS	120.22
Power		Peak	168.42
KW	0.20	DC Offset	0.17
KVA	0.25	Crest	1.4
KVAR	0.08	THD Rms	1.39
Peak KW	0.68	THD Fund	1.39
Phase	22° lag	HRMS	1.67
Total PF	0.82	KFactor	11.10
DPF	0.93		



Vacuum Cleaner
Model - Eureka 6865
Ratings - 120V, 12A

Normal Voltage Condition

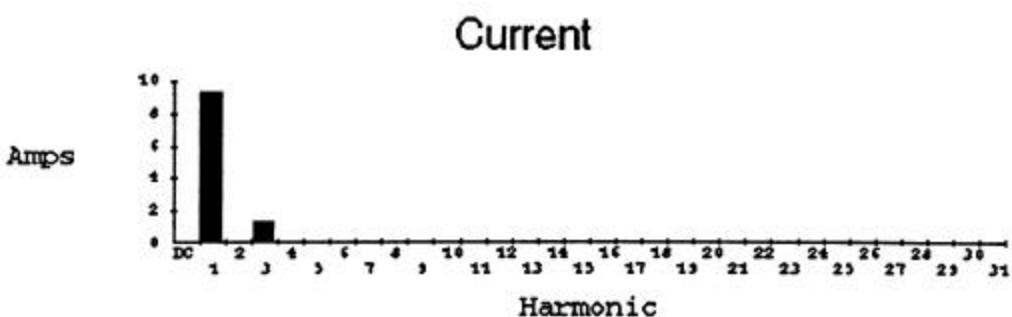
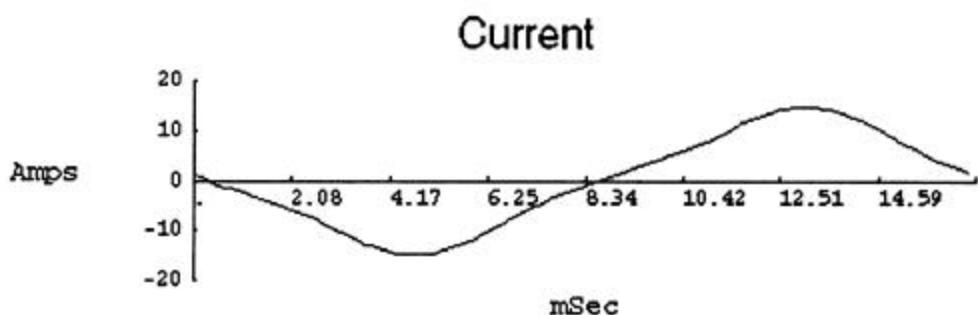
		Voltage	Current
Frequency	59.98	RMS	120.57
Power		Peak	168.54
KW	-1.25	DC Offset	0.16
KVA	1.27	Crest	1.4
KVAR	0.17	THD Rms	1.42
Peak KW	-2.84	THD Fund	1.42
Phase	172° lead	HRMS	1.71
Total PF	-0.98	KFactor	1.24
DPF	-0.99		



Vacuum Cleaner
Model - Eureka 6865
Ratings - 120V, 12A

Low Voltage Condition

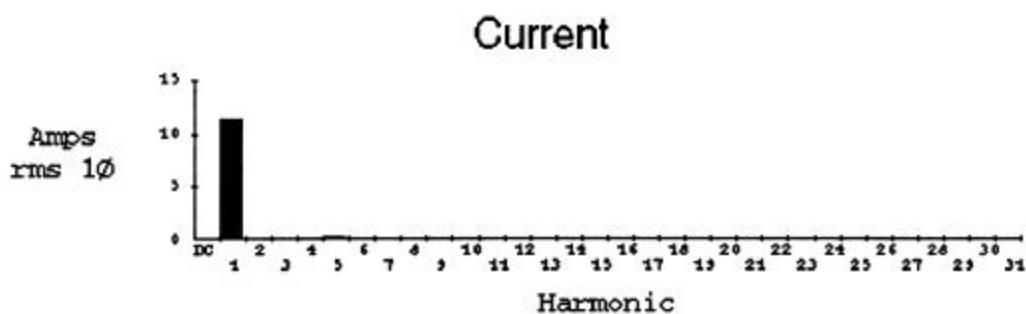
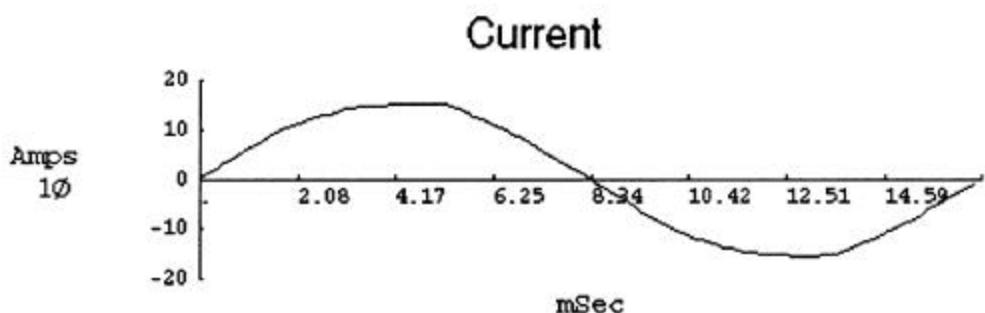
		Voltage	Current
Frequency	59.98	RMS	108.39
Power		Peak	151.50
KW	-1.01	DC Offset	0.17
KVA	1.03	Crest	1.4
KVAR	0.14	THD Rms	1.41
Peak KW	-2.28	THD Fund	1.41
Phase	172° lead	HRMS	1.53
Total PF	-0.98	KFactor	1.16
DPF	-0.99		



Portable Heater
Model - Servess
Ratings - 120V, 50-60 Hz

Normal Voltage Condition

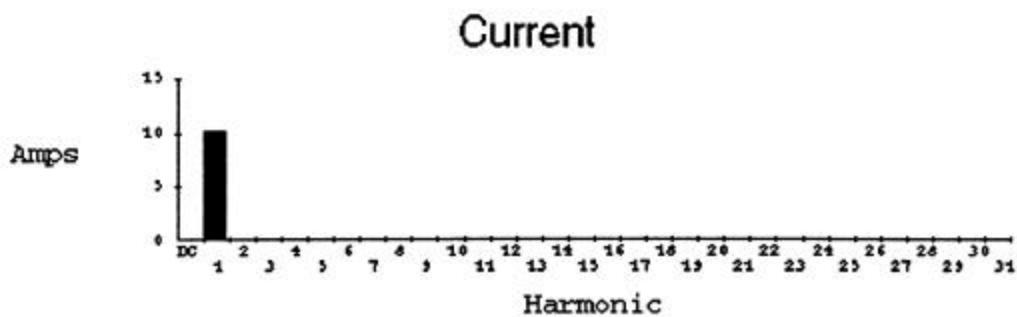
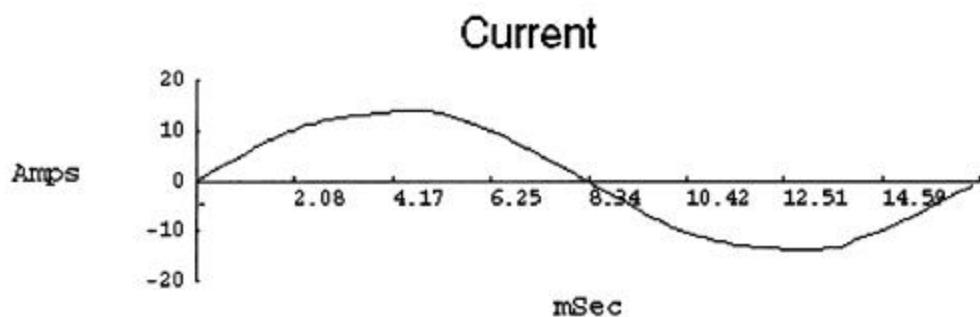
		Voltage	Current
Frequency	59.96	RMS	120.42
Power		Peak	168.83
KW	1.37	DC Offset	0.01
KVA	1.37	Crest	1.4
KVAR	0.02	THD Rms	2.66
Peak KW	2.67	THD Fund	2.66
Phase	1° lead	HRMS	3.20
Total PF	1.00	KFactor	1.02
DPF	1.00		



Portable Heater
Model - Servess
Ratings - 120V, 50-60 Hz

Low Voltage Condition

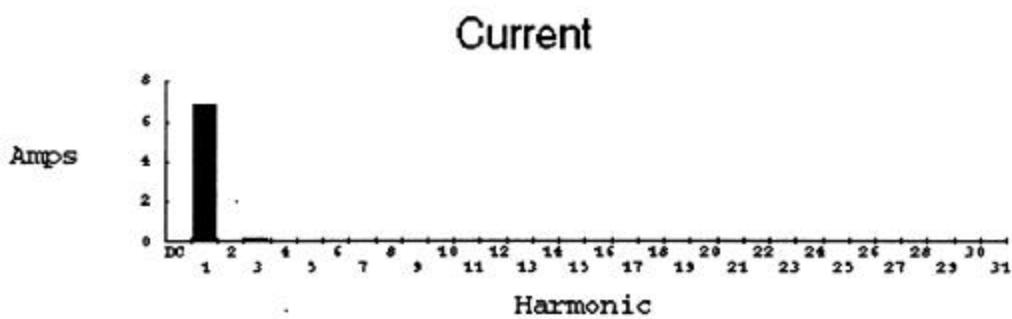
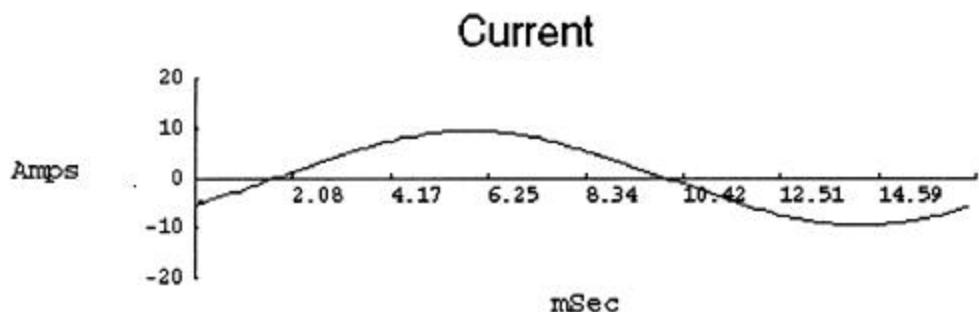
		Voltage	Current
Frequency	59.96	RMS	107.92
Power		Peak	151.03
KW	1.10	DC Offset	-0.01
KVA	1.10	Crest	1.39
KVAR	0.01	THD Rms	2.70
Peak KW	2.14	THD Fund	2.70
Phase	1° lead	HRMS	2.56
Total PF	1.00	KFactor	1.02
DPF	1.00		



House Fan
Model - Emerson WHF1130
Ratings - 120V

Normal Voltage Condition at high speed

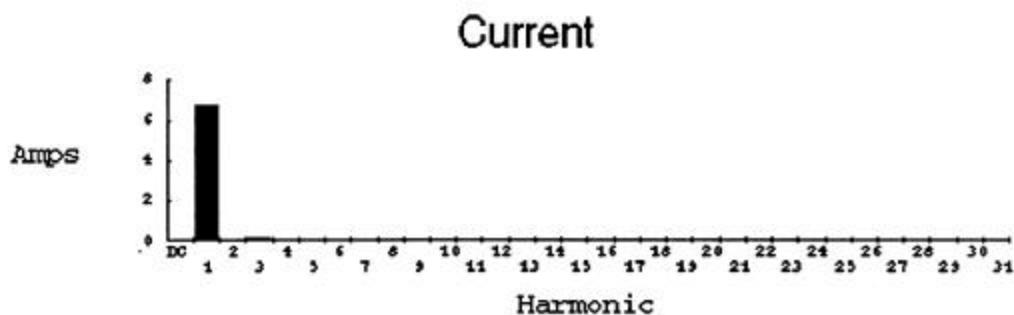
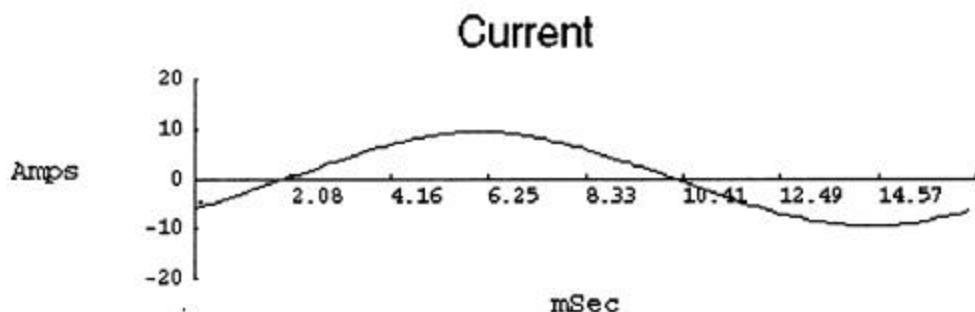
		Voltage	Current
Frequency	59.98	RMS	113.83
Power		Peak	159.63
KW	0.62	DC Offset	0.15
KVA	0.77	Crest	1.44
KVAR	0.47	THD Rms	1.37
Peak KW	1.42	THD Fund	1.37
Phase	37° lag	HRMS	1.56
Total PF	0.80	KFactor	1.02
DPF	0.80		



House Fan
Model - Emerson WHF1130
Ratings - 120V

Low Voltage Condition at high speed

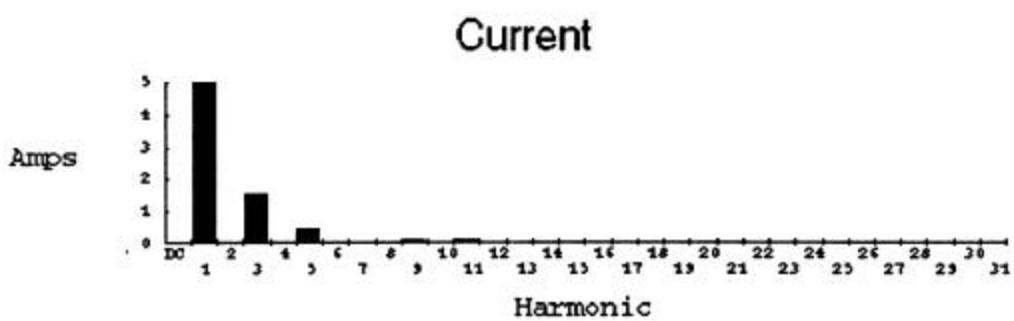
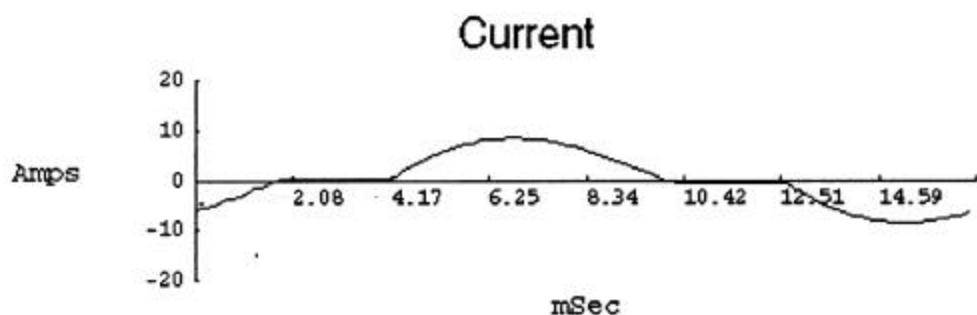
		Voltage	Current
Frequency	60.04	RMS	101.86
Power		Peak	142.88
KW	0.52	DC Offset	0.04
KVA	0.69	Crest	1.4
KVAR	0.45	THD Rms	1.42
Peak KW	1.24	THD Fund	1.42
Phase	41° lag	HRMS	2.49
Total PF	0.76	KFactor	0.17
DPF	0.76		1.01



House Fan
Model - Emerson WHF1130
Ratings - 120V

Normal Voltage Condition at low speed

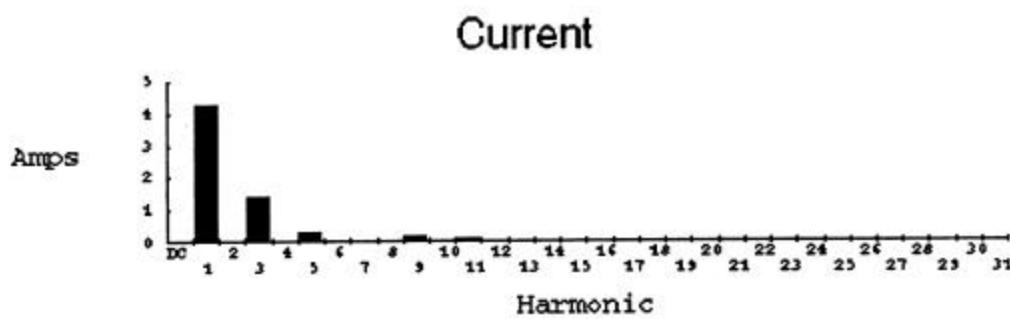
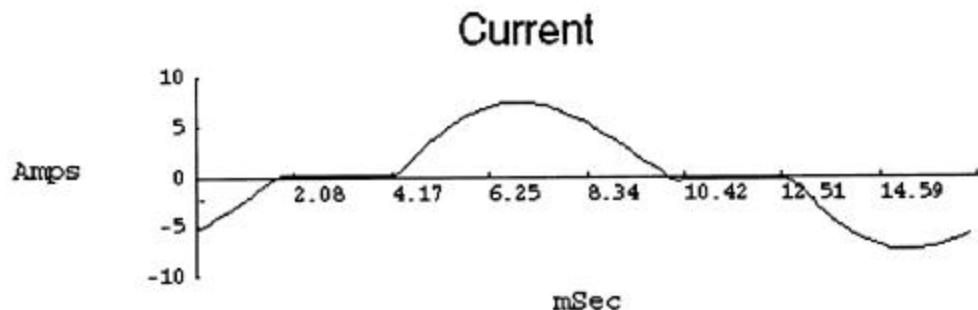
		Voltage	Current
Frequency	59.98	RMS	115.89
Power		Peak	164.83
KW	0.30	DC Offset	0.07
KVA	0.61	Crest	1.42
KVAR	0.50	THD Rms	1.79
Peak KW	1.02	THD Fund	1.79
Phase	59° lag	HRMS	2.07
Total PF	0.50	KFactor	1.99
DPF	0.51		



House Fan
Model - Emerson WHF1130
Ratings - 120V

Low Voltage Condition at low speed

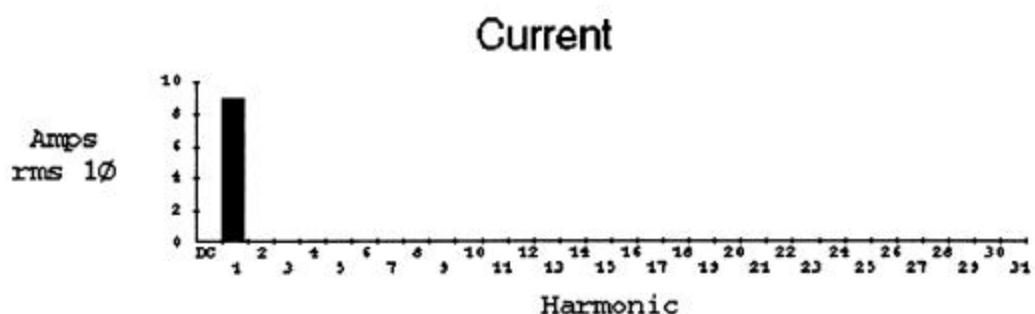
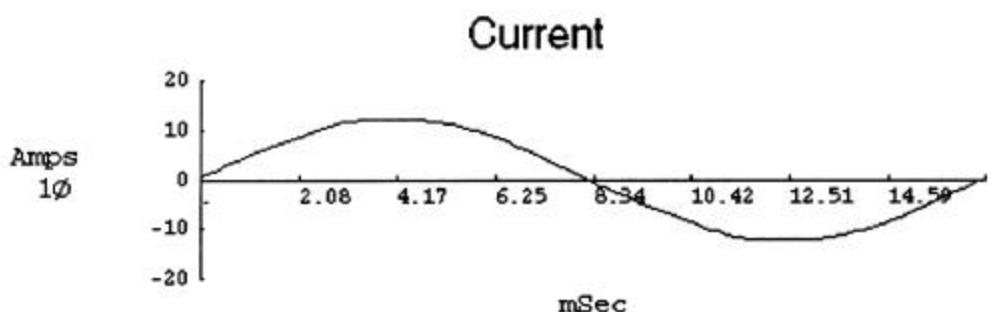
		Voltage	Current
Frequency	59.98	RMS	103.92
Power		Peak	148.20
KW	0.22	DC Offset	0.08
KVA	0.46	Crest	1.43
KVAR	0.38	THD Rms	1.80
Peak KW	0.77	THD Fund	1.80
Phase	60° lag	HRMS	1.87
Total PF	0.47	KFactor	2.11
DPF	0.50		



Hair Dryer
Model – Braun 4583
Ratings – 120V, 1200W

High Power Setting
Normal Voltage Condition

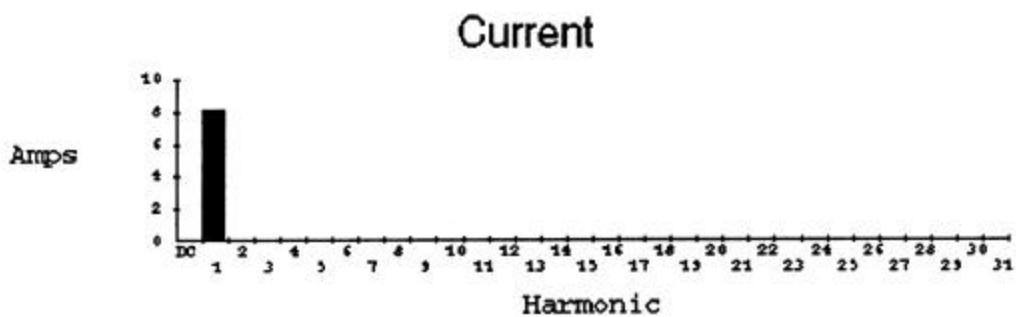
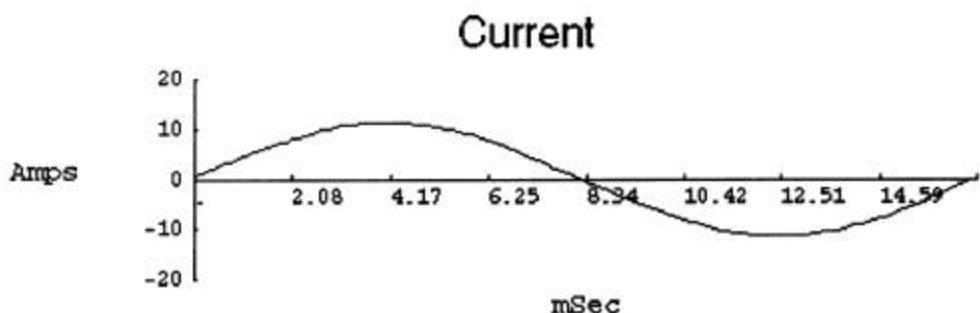
		Voltage	Current
Frequency	59.98	RMS	120.10
Power		Peak	168.30
KW	1.07	DC Offset	0.10
KVA	1.07	Crest	1.4
KVAR	0.04	THD Rms	1.46
Peak KW	2.12	THD Fund	1.46
Phase	2° lead	HRMS	1.75
Total PF	1.00	KFactor	1.01
DPF	1.00		



Hair Dryer
Model – Braun 4583
Ratings – 120V, 1200W

High Power Setting
Low Voltage Condition

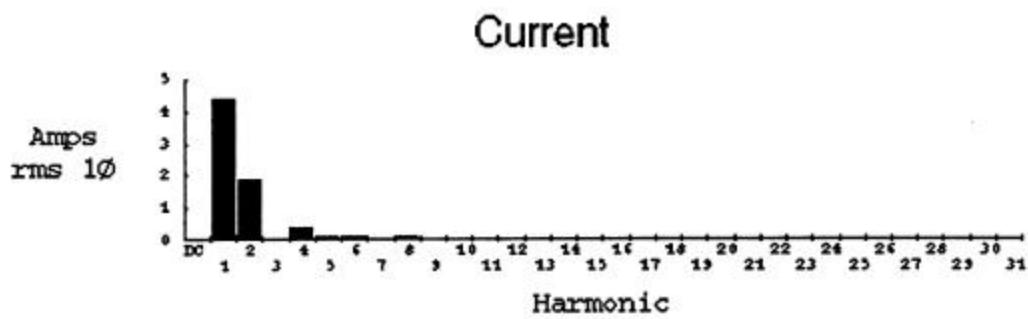
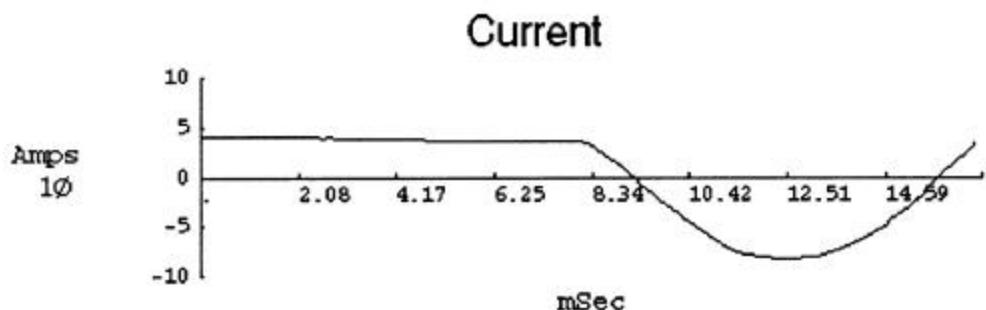
		Voltage	Current
Frequency	59.98	RMS	108.81
Power		Peak	152.52
KW	0.89	DC Offset	0.11
KVA	0.89	Crest	1.4
KVAR	0.03	THD Rms	1.45
Peak KW	1.75	THD Fund	1.45
Phase	2° lead	HRMS	1.57
Total PF	1.00	KFactor	1.01
DPF	1.00		



Hair Dryer
Model – Braun 4583
Ratings – 120V, 1200W

Low Power Setting
Normal Voltage Condition

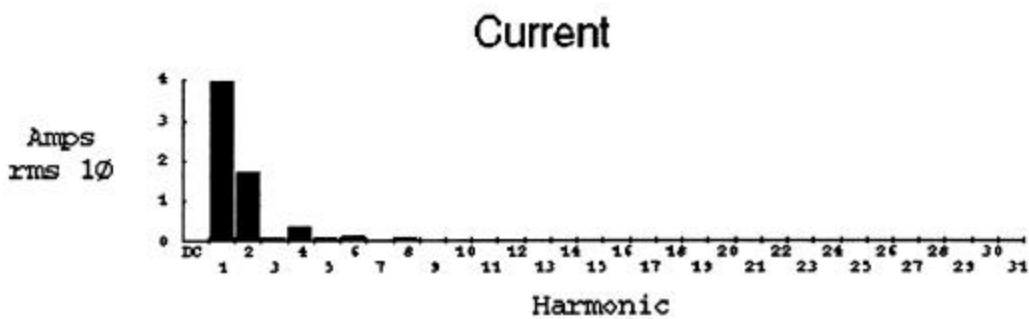
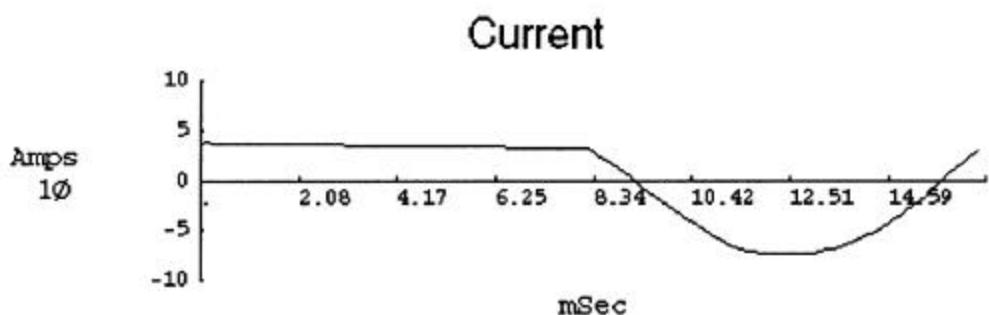
		Voltage	Current
Frequency	59.98	RMS	120.19
Power		Peak	168.71
KW	0.52	DC Offset	1.56
KVA	0.58	Crest	1.4
KVAR	0.02	THD Rms	3.33
Peak KW	1.39	THD Fund	3.34
Phase	2° lead	HRMS	4.01
Total PF	0.91	KFactor	1.64
DPF	1.00		



Hair Dryer
Model – Braun 4583
Ratings – 120V, 1200W

Low Power Setting
Low Voltage Condition

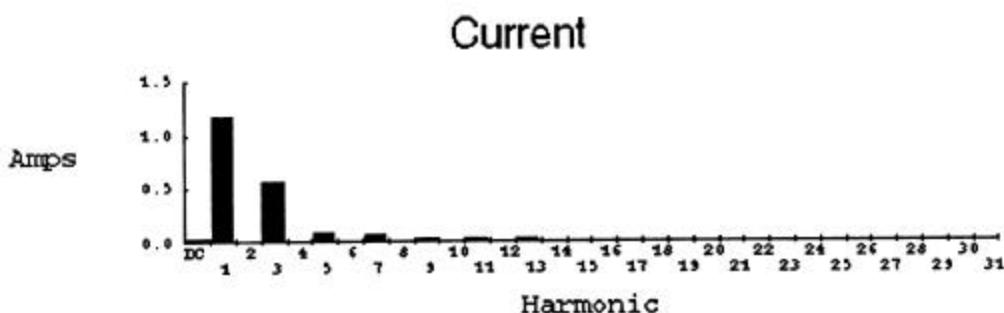
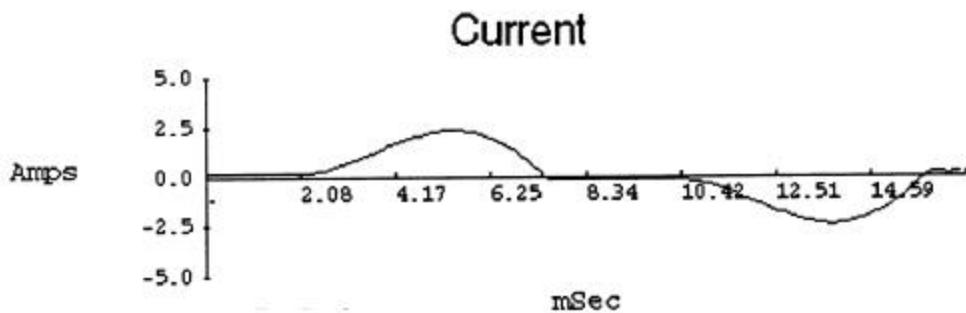
		Voltage	Current
Frequency	59.98	RMS	108.38
Power		Peak	152.16
KW	0.43	DC Offset	1.36
KVA	0.47	Crest	1.4
KVAR	0.01	THD Rms	2.79
Peak KW	1.14	THD Fund	2.79
Phase	2° lead	HRMS	3.02
Total PF	0.91	KFactor	1.64
DPF	1.00		



**Garbage Disposal Unit
Model - Sinkmaster 801
Ratings - 115V, 4.5A**

Normal Voltage Condition

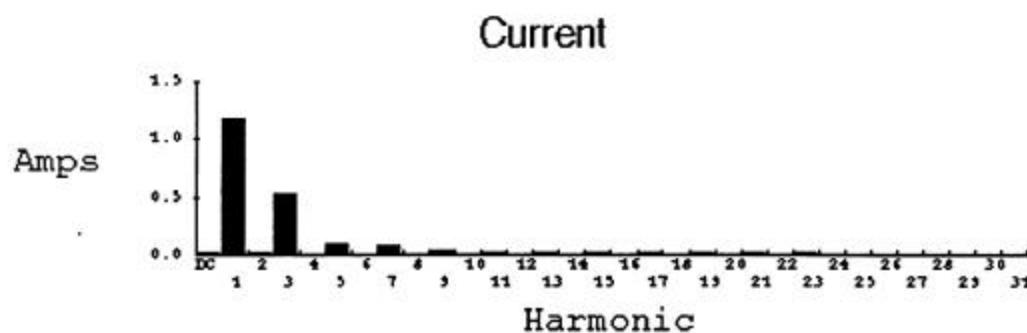
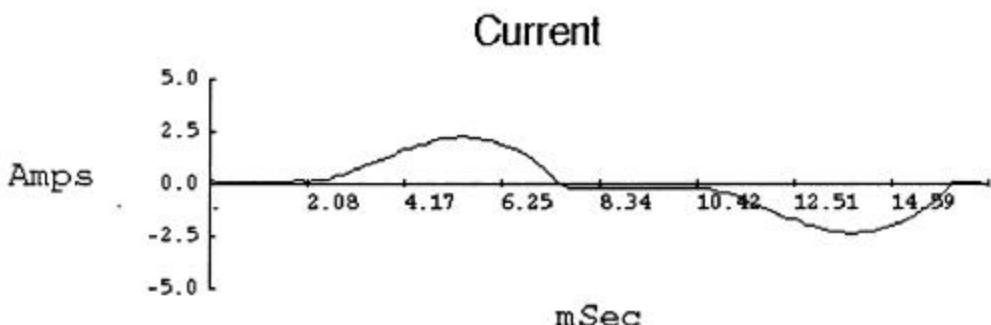
		Voltage	Current
Frequency	59.98	RMS	118.34
Power		Peak	166.04
Watts	134.79	DC Offset	0.09
VA	155.89	Crest	1.4
Vars	40.26	THD Rms	1.26
Peak W	381.73	THD Fund	1.26
Phase	17° lag	HRMS	1.49
Total PF	0.87	KFactor	3.03
DPF	0.96		



**Garbage Disposal Unit
Model - Sinkmaster 801
Ratings - 115V, 4.5A**

Low Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	104.94
Power		Peak	147.17
Watts	117.79	DC Offset	0.08
VA	135.89	Crest	1.4
Vars	38.26	THD Rms	1.20
Peak W	328.73	THD Fund	1.20
Phase	18° lag	HRMS	1.26
Total PF	0.87	KFactor	0.54
DPF	0.95		2.86



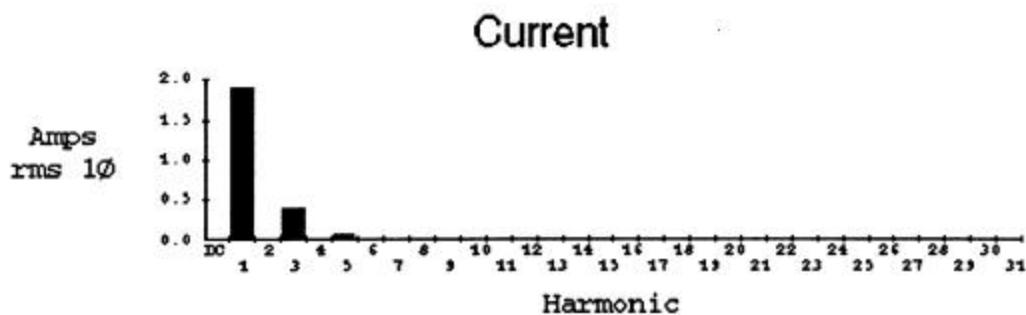
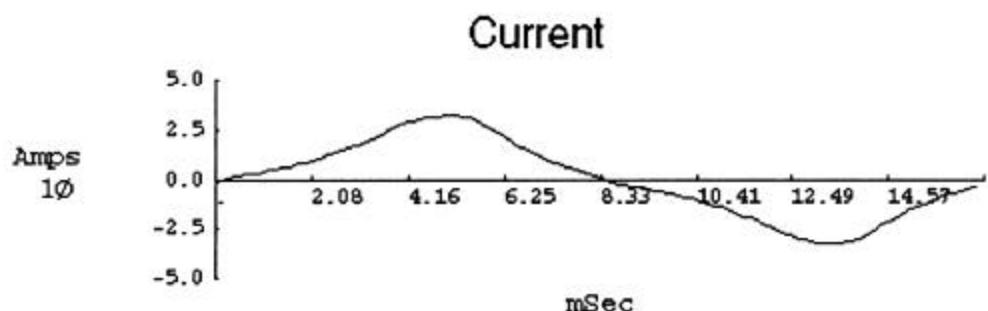
Drill

Model - Ryobi D38VSR

Ratings - 120V, 4A (Yr - 1995)

Normal Voltage Condition

		Voltage	Current
Frequency	60.04	RMS	119.46
Power		Peak	167.81
KW	0.22	DC Offset	0.11
KVA	0.23	Crest	1.4
KVAR	0.04	THD Rms	1.92
Peak KW	0.55	THD Fund	1.92
Phase	11° lag	HRMS	2.29
Total PF	0.96	KFactor	1.43
DPF	0.98		



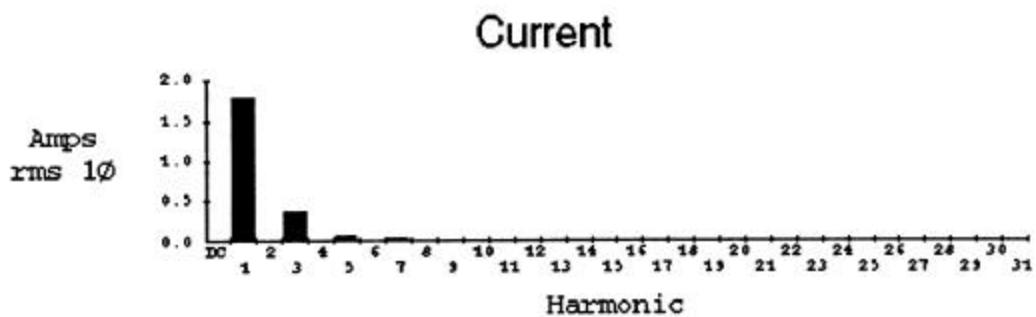
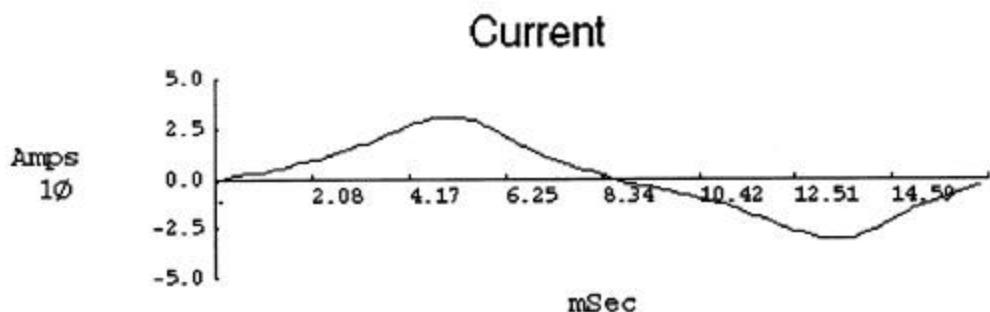
Drill

Model - Ryobi D38VSR

Ratings - 120V, 4A (Yr - 1995)

Low Voltage Condition

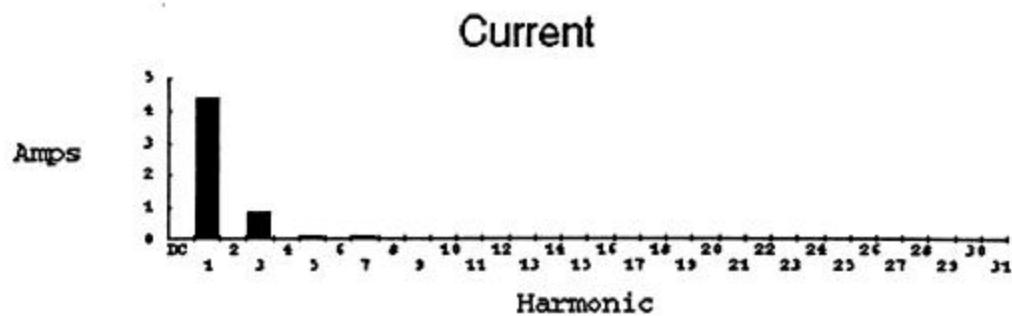
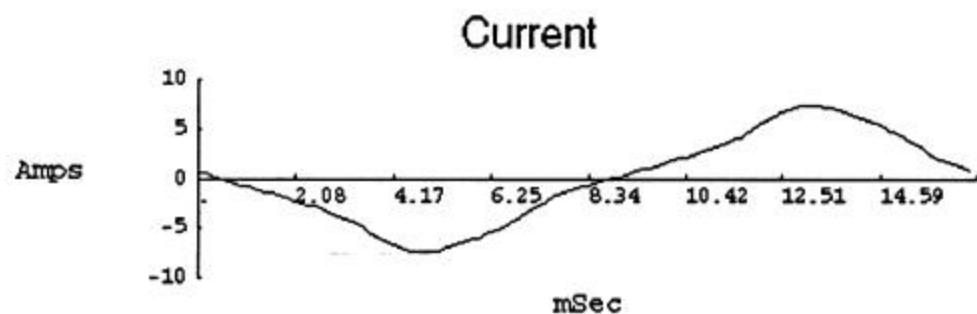
		Voltage	Current
Frequency	59.98	RMS	1.84
Power		Peak	3.12
KW	0.19	DC Offset	-0.02
KVA	0.20	Crest	1.69
KVAR	0.04	THD Rms	20.01
Peak KW	0.47	THD Fund	20.42
Phase	12° lag	HRMS	0.37
Total PF	0.96	KFactor	1.40
DPF	0.98		



Garage Door
Model - Sears (S. No. 139.6530000)
Ratings - 117V, 4.5A

Normal Voltage Condition

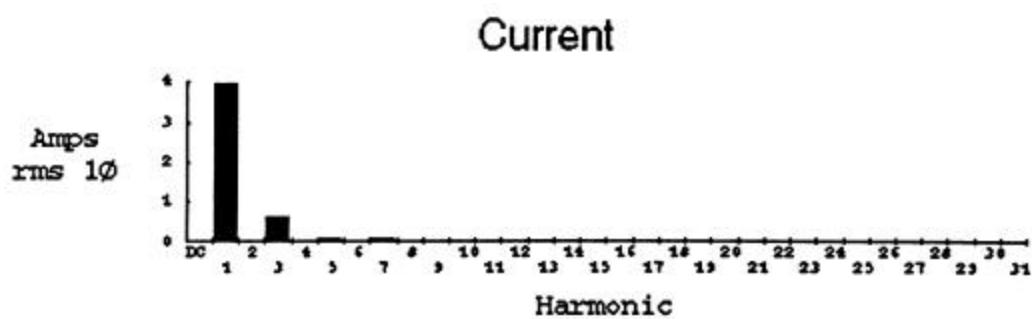
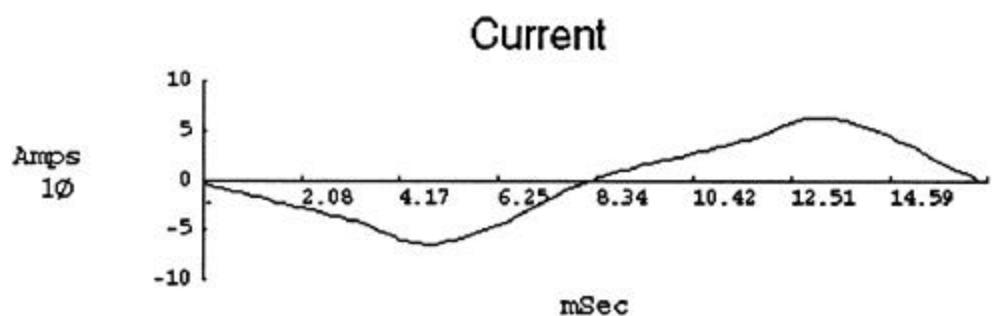
		Voltage	Current
Frequency	59.98	RMS	118.01
Power		Peak	165.13
KW	-0.51	DC Offset	0.19
KVA	0.53	Crest	1.4
KVAR	0.11	THD Rms	1.42
Peak KW	-1.24	THD Fund	1.42
Phase	167° lead	HRMS	1.68
Total PF	-0.95	KFactor	0.84
DPF	-0.98		1.32



Garage Door
Model - Sears (S. No. 139.6530000)
Ratings - 117V, 4.5A

Low Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	106.86
Power		Peak	149.21
KW	-0.42	DC Offset	0.19
KVA	0.43	Crest	1.4
KVAR	0.05	THD Rms	1.43
Peak KW	-0.98	THD Fund	1.43
Phase	174° lead	HRMS	16.45
Total PF	-0.98	KFactor	16.68
DPF	-0.99		0.66
			1.25





Appendix A.6

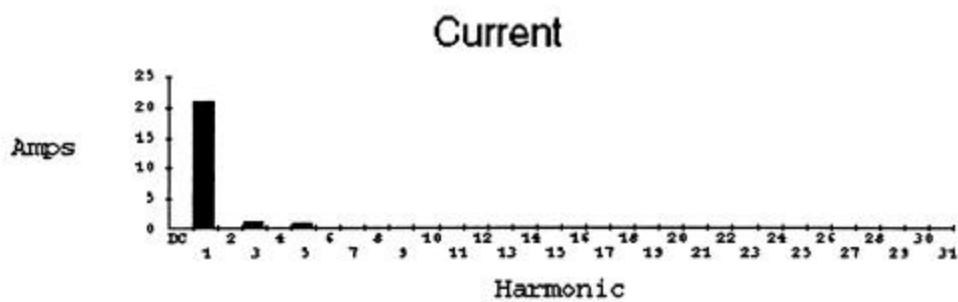
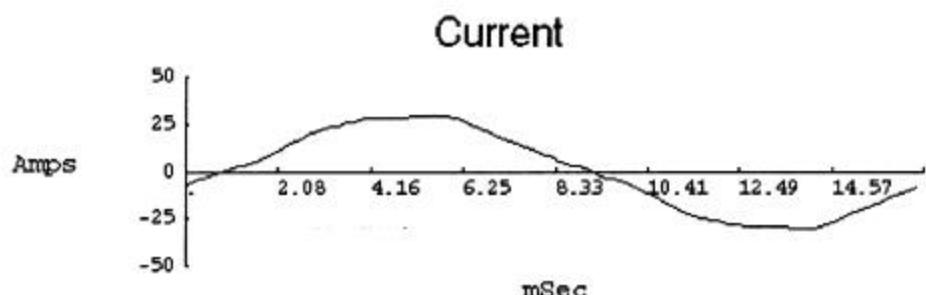
Heating and Related Equipment



Heat Pump
Model - Water Furnace Inc. ATV057A110CLT
Ratings - 208-240V, 35.4FLA (Yr - 1994)

Normal Voltage Condition at high power

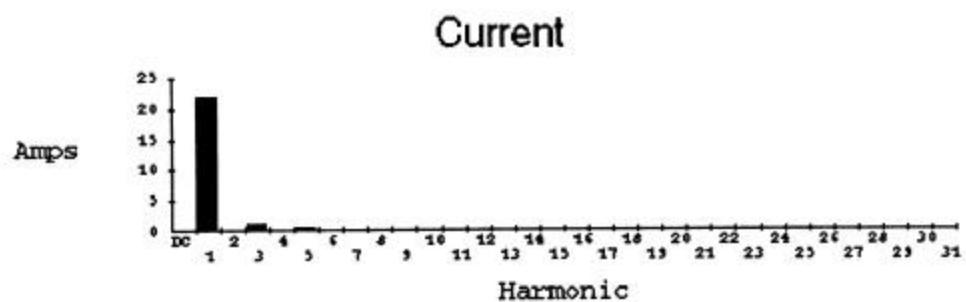
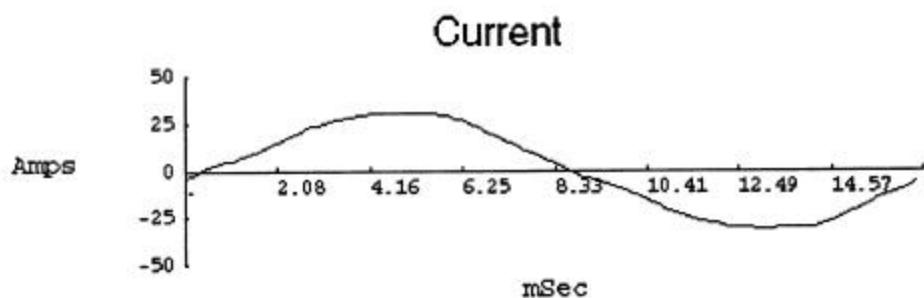
		Voltage	Current
Frequency	60.04	RMS	241.0
Power		Peak	342.5
KW	4.81	DC Offset	-0.1
KVA	5.04	Crest	1.42
KVAR	1.58	THD Rms	2.22
Peak KW	10.11	THD Fund	2.22
Phase	18° lag	HRMS	5.4
Total PF	0.95	KFactor	1.10
DPF	0.95		



Heat Pump
Model - Water Furnace Inc. ATV057A110CLT
Ratings - 208-240V, 35.4FLA (Yr - 1994)

Low Voltage Condition at high power

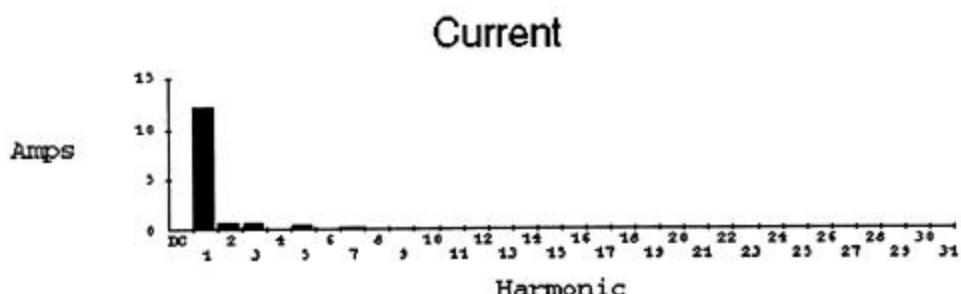
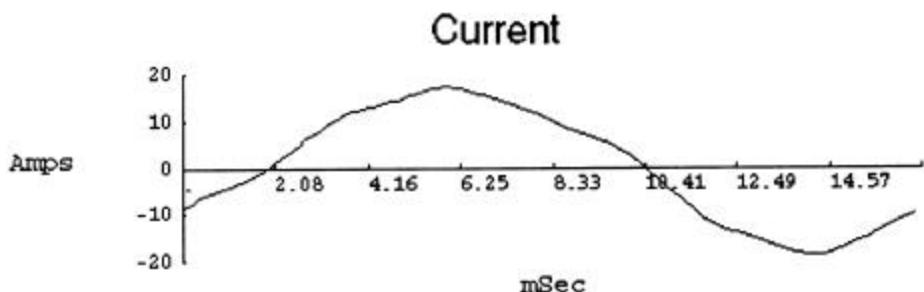
		Voltage	Current
Frequency	60.04	RMS	216.1
Power		Peak	306.7
KW	4.69	DC Offset	-0.2
KVA	4.78	Crest	1.43
KVAR	0.93	THD Rms	2.04
Peak KW	9.69	THD Fund	2.04
Phase	11° lag	HRMS	4.4
Total PF	0.98	KFactor	1.07
DPF	0.98		



Heat Pump
Model - Water Furnace Inc. ATV057A110CLT
Ratings - 208-240V, 35.4FLA (Yr - 1994)

Normal Voltage Condition at medium power

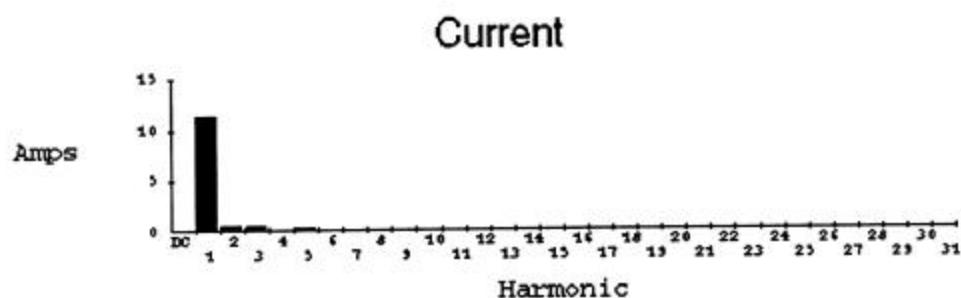
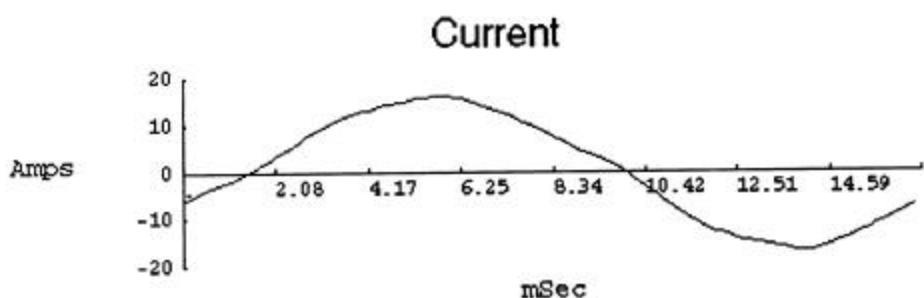
		Voltage	Current
Frequency	60.04	RMS	241.0
Power		Peak	338.0
KW	2.32	DC Offset	-0.1
KVA	2.96	Crest	1.4
KVAR	1.84	THD Rms	2.30
Peak KW	5.80	THD Fund	2.30
Phase	39° lag	HRMS	5.5
Total PF	0.78	KFactor	1.05
DPF	0.78		1.10



Heat Pump
Model - Water Furnace Inc. ATV057A110CLT
Ratings - 208-240V, 35.4FLA (Yr - 1994)

Low Voltage Condition at medium power

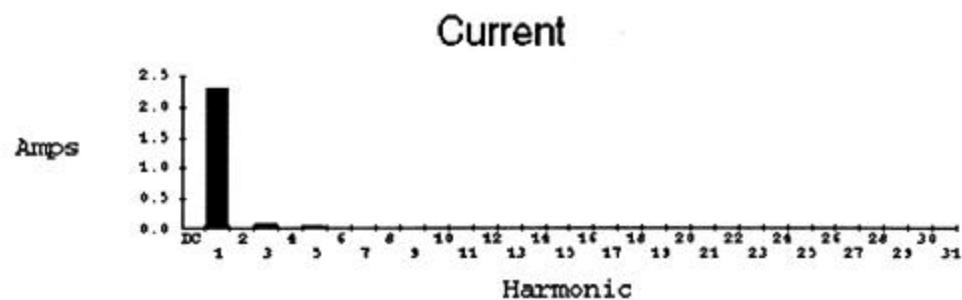
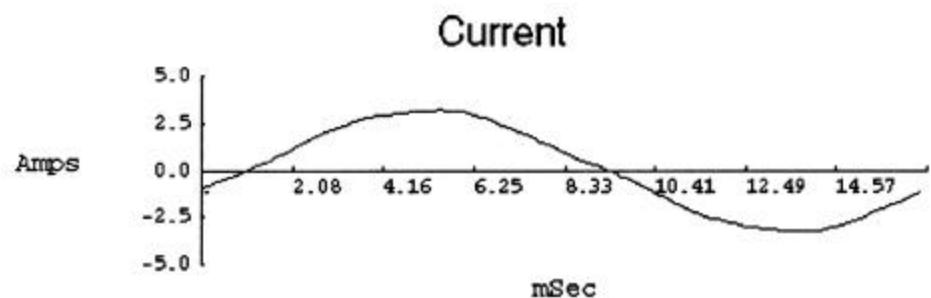
		Voltage	Current
Frequency	59.98	RMS	216.1
Power		Peak	303.2
KW	2.13	DC Offset	0.3
KVA	2.46	Crest	1.4
KVAR	1.23	THD Rms	2.16
Peak KW	4.84	THD Fund	2.16
Phase	30° lag	HRMS	4.7
Total PF	0.87	KFactor	1.05
DPF	0.86		



Heat Pump
Model - Water Furnace Inc. ATV057A110CLT
Ratings - 208-240V, 35.4FLA (Yr - 1994)

Normal Voltage Condition at low power

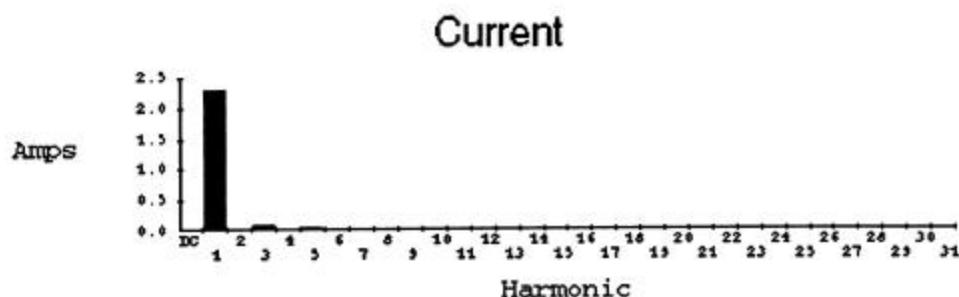
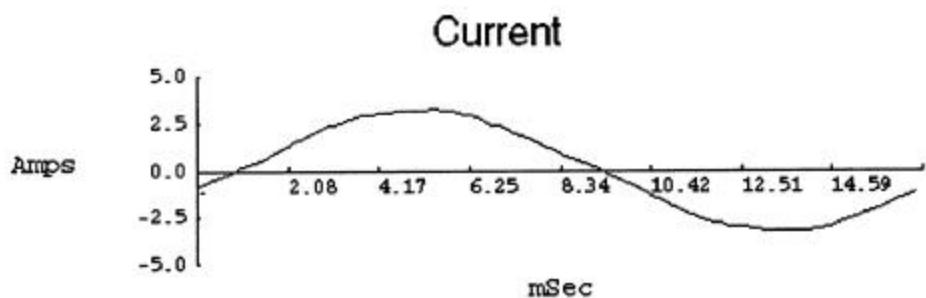
		Voltage	Current
Frequency	60.04	RMS	240.2
Power		Peak	337.1
KW	0.51	DC Offset	0.0
KVA	0.55	Crest	1.4
KVAR	0.20	THD Rms	2.33
Peak KW	1.09	THD Fund	2.33
Phase	21° lag	HRMS	5.6
Total PF	0.93	KFactor	1.05
DPF	0.93		



Heat Pump
Model - Water Furnace Inc. ATV057A110CLT
Ratings - 208-240V, 35.4FLA (Yr - 1994)

Low Voltage Condition at low power

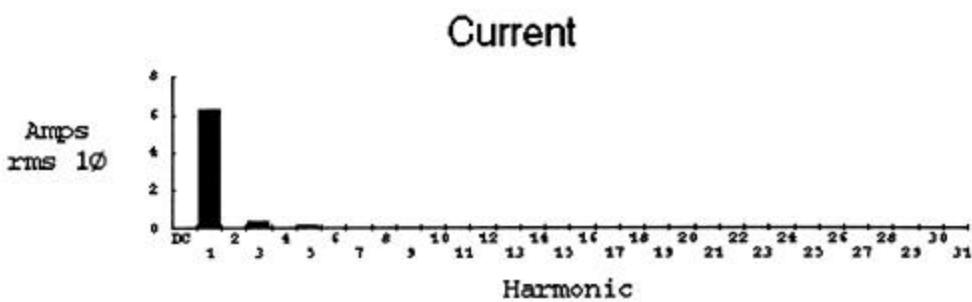
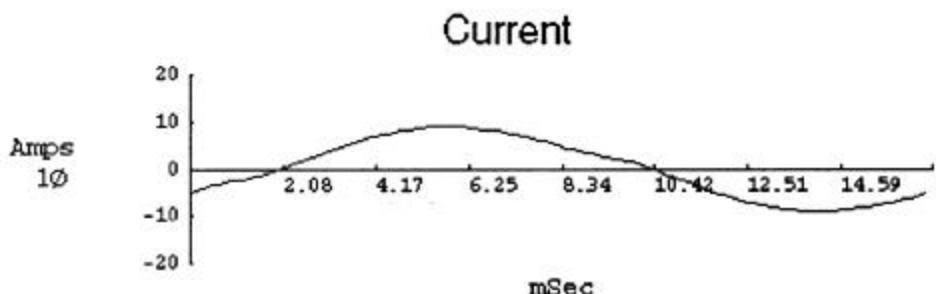
		Voltage	Current
Frequency	59.98	RMS	216.8
Power		Peak	304.2
KW	0.48	DC Offset	0.1
KVA	0.50	Crest	1.4
KVAR	0.16	THD Rms	2.29
Peak KW	0.99	THD Fund	2.29
Phase	19° lag	HRMS	5.0
Total PF	0.95	KFactor	1.04
DPF	0.95		



Water Pump
Model - Franklin Electric 2445050117
Ratings - 230V, 0.37KW, 5A (Yr - 1994)

Normal Voltage Condition

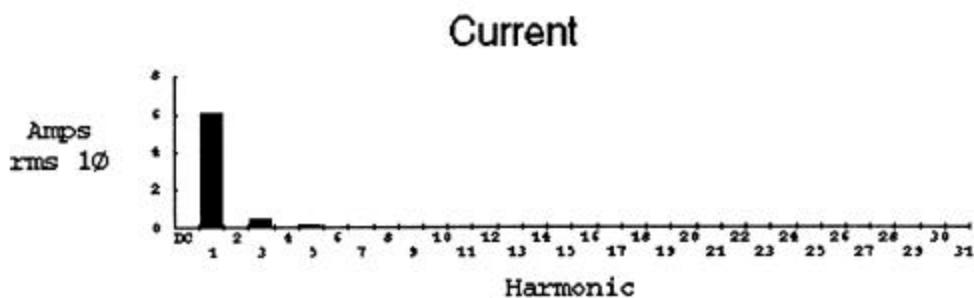
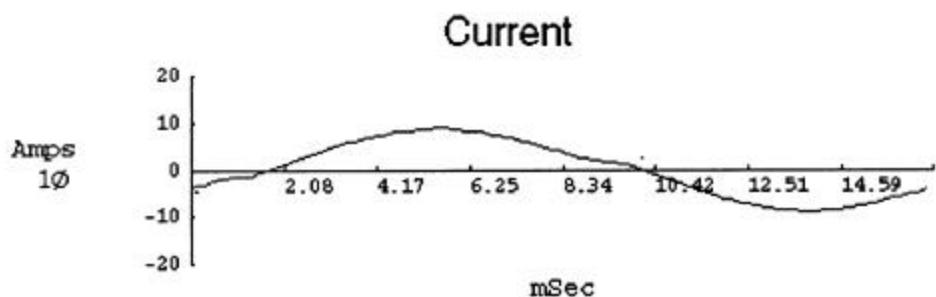
		Voltage	Current
Frequency	59.98	RMS	240.5
Power		Peak	338.3
KW	1.18	DC Offset	0.0
KVA	1.51	Crest	1.49
KVAR	0.94	THD Rms	1.92
Peak KW	2.91	THD Fund	1.92
Phase	39° lag	HRMS	4.6
Total PF	0.78	KFactor	1.06
DPF	0.78		



Water Pump
Model - Franklin Electric 2445050117
Ratings - 230V, 0.37KW, 5A (Yr - 1994)

Low Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	217.1
Power		Peak	305.1
KW	1.11	DC Offset	0.0
KVA	1.32	Crest	1.41
KVAR	0.70	THD Rms	1.88
Peak KW	2.61	THD Fund	1.88
Phase	32° lag	HRMS	4.1
Total PF	0.84	KFactor	1.08
DPF	0.84		

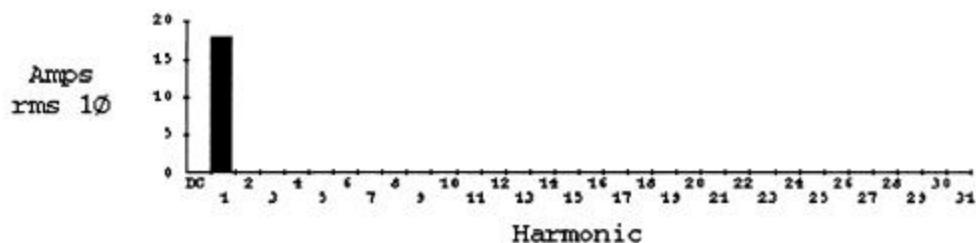


Water Heater
Model - A.O. Smith EES52913
Ratings - 240V, 4.5KW (Yr - 1994)

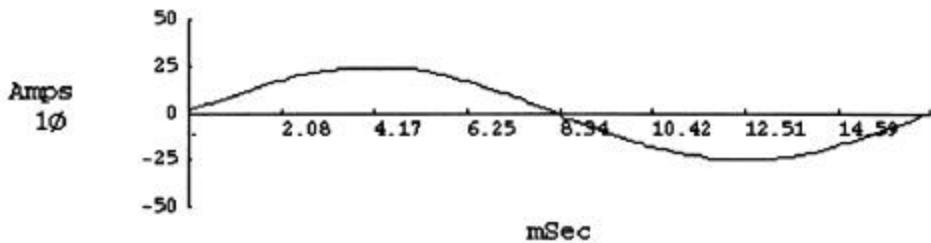
Normal Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	240.4
Power		Peak	338.0
KW	4.33	DC Offset	0.3
KVA	4.33	Crest	1.40
KVAR	0.05	THD Rms	1.94
Peak KW	8.60	THD Fund	1.94
Phase	1° lead	HRMS	4.7
Total PF	1.00	KFactor	1.04
DPF	1.00		

Current



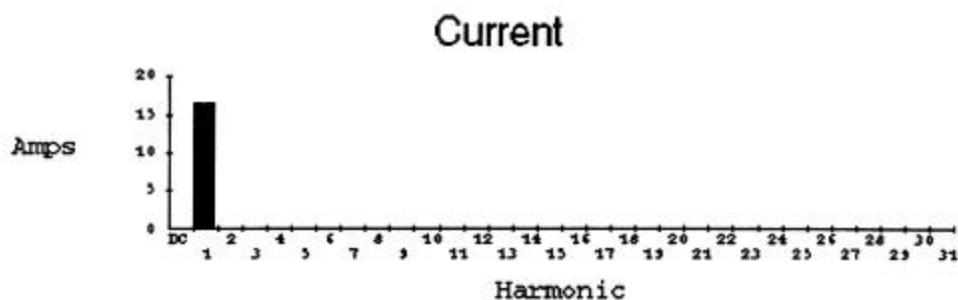
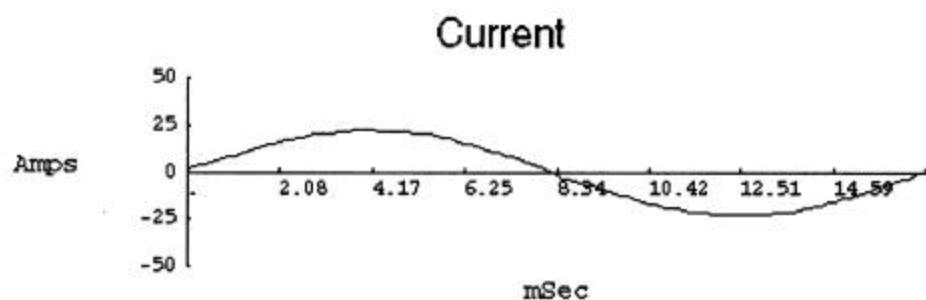
Current



Water Heater
Model - A.O. Smith EES52913
Ratings - 240V, 4.5KW (Yr - 1994)

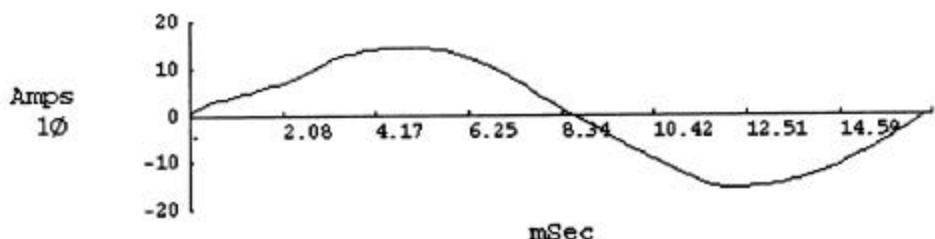
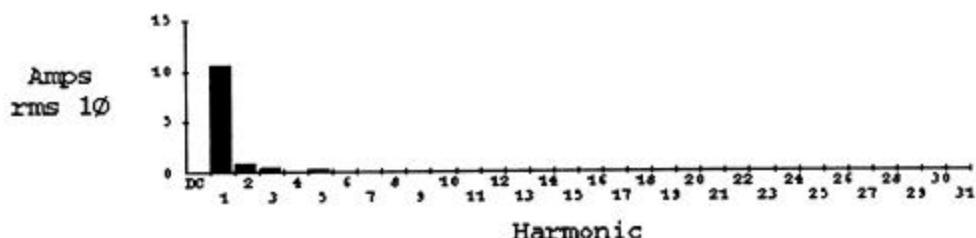
Low Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	216.6
Power		Peak	304.4
KW	3.55	DC Offset	-0.1
KVA	3.55	Crest	1.40
KVAR	0.13	THD Rms	1.93
Peak KW	7.04	THD Fund	1.94
Phase	2° lead	HRMS	4.2
Total PF	1.00	KFactor	1.05
DPF	1.00		



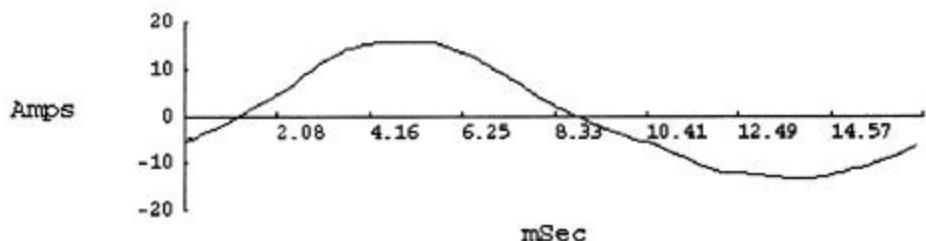
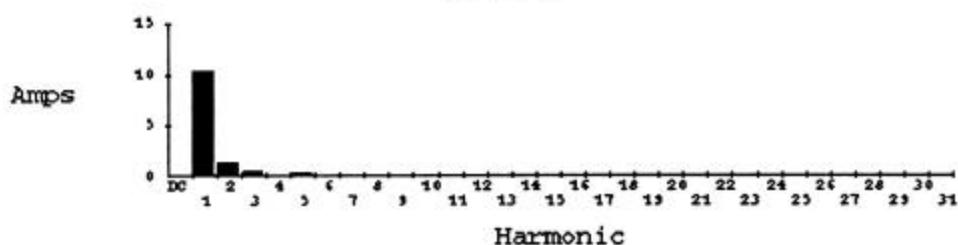
Air Conditioner**Model - America Standard ATJ024A100A0****Year of manufacture - 1970****Ratings 230V, 15.3A****Low Voltage Condition**

		Voltage	Current
Frequency	59.98	RMS	212.3
Power		Peak	298.8
KW	2.22	DC Offset	0.1
KVA	2.24	Crest	1.41
KVAR	0.25	THD Rms	1.39
Peak KW	4.74	THD Fund	1.39
Phase	6° lag	HRMS	3.0
Total PF	0.99	KFactor	1.07
DPF	0.99		

Current**Current**

Air Conditioner**Model - America Standard ATJ024A100A0****Year of manufacture - 1970****Ratings 230V,15.3A****Normal Voltage Condition**

		Voltage	Current
Frequency	60.04	RMS	237.7
Power		Peak	334.6
KW	2.32	DC Offset	-0.1
KVA	2.48	Crest	1.41
KVAR	0.83	THD Rms	1.52
Peak KW	5.34	THD Fund	1.52
Phase	20° lag	HRMS	3.6
Total PF	0.93	KFactor	1.09
DPF	0.94		

Current**Current**



Appendix A.7

Other High Power Appliances



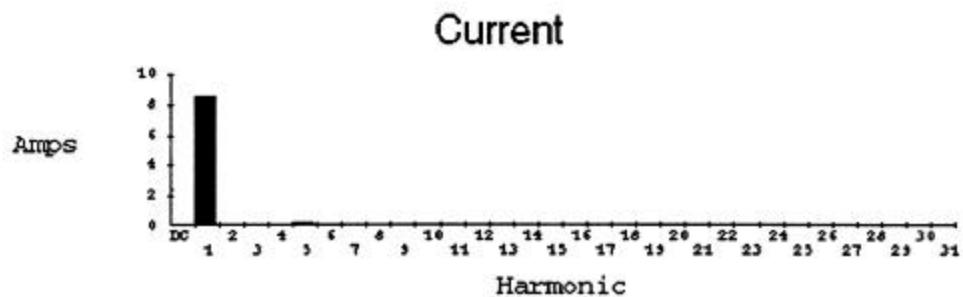
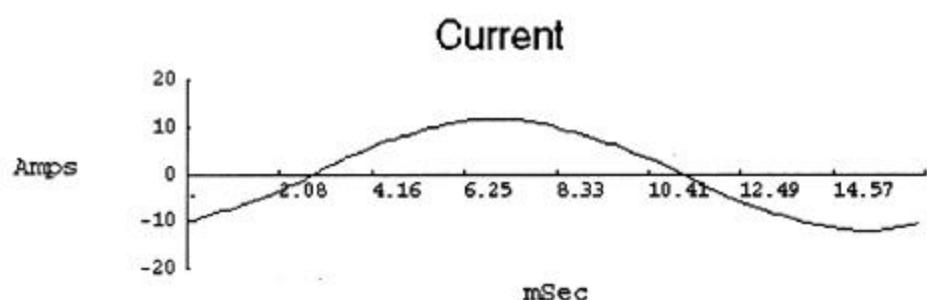
Washing Machine

Model - Kenmore S.No. 110.82980120 (1991)

Ratings - 120V, 10A

Normal Voltage Condition

		Voltage	Current
Frequency	60.04	RMS	116.31
Power		Peak	163.02
KW	0.48	DC Offset	0.05
KVA	0.99	Crest	1.4
KVAR	0.86	THD Rms	1.50
Peak KW	1.47	THD Fund	1.50
Phase	61° lag	HRMS	1.74
Total PF	0.48	KFactor	1.01
DPF	0.48		



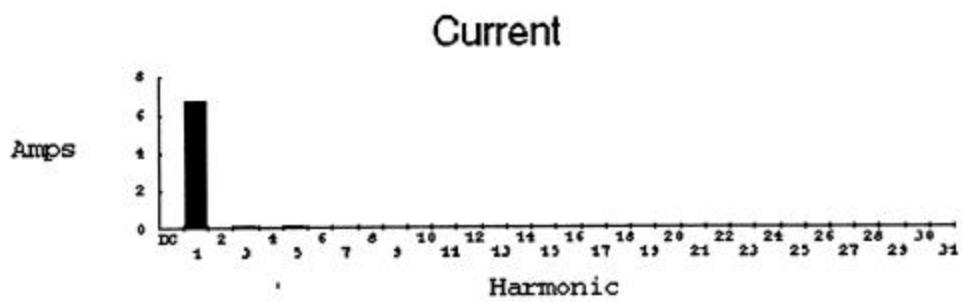
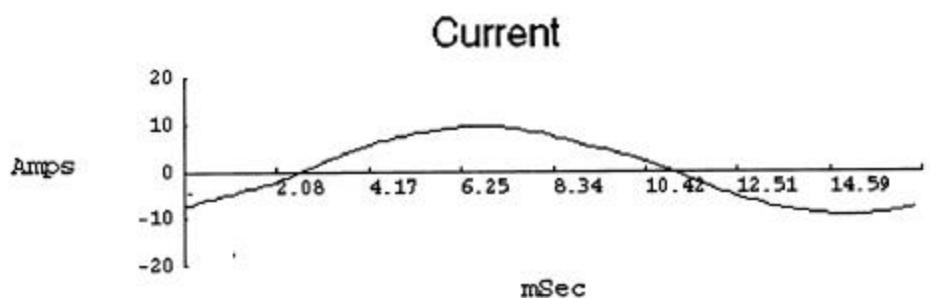
Washing Machine

Model - Kenmore S.No. 110.82980120 (1991)

Ratings - 120V, 10A

Low Voltage Condition

		Voltage	Current
Frequency	59.98	RMS	105.62
Power		Peak	9.72
KW	0.41	DC Offset	0.19
KVA	0.73	Crest	1.4
KVAR	0.59	THD Rms	1.35
Peak KW	1.14	THD Fund	3.93
Phase	56° lag	HRMS	0.27
Total PF	0.56	KFactor	1.02
DPF	0.56		



Washing Machine

Model - Kenmore S.No. 110.82980120 (1991)

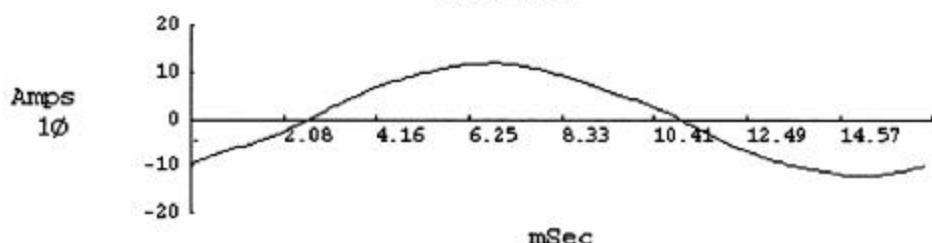
Ratings - 120V, 10A

Spin Cycle

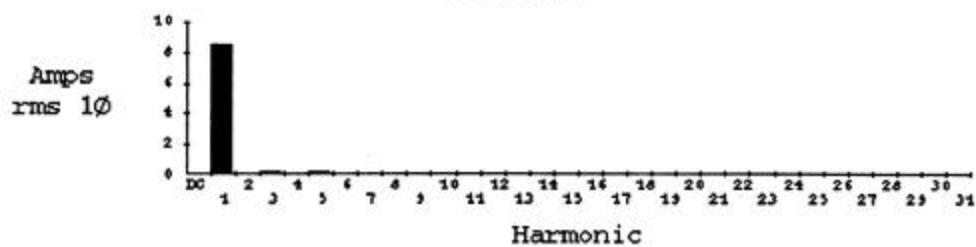
Normal Voltage Condition

		Voltage	Current
Frequency	60.04	RMS	116.19
Power		Peak	162.84
KW	0.56	DC Offset	0.06
KVA	0.99	Crest	1.4
KVAR	0.82	THD Rms	1.43
Peak KW	1.57	THD Fund	1.43
Phase	56° lag	HRMS	2.98
Total PF	0.57	KFactor	0.25
DPF	0.56		1.02

Current



Current



Washing Machine

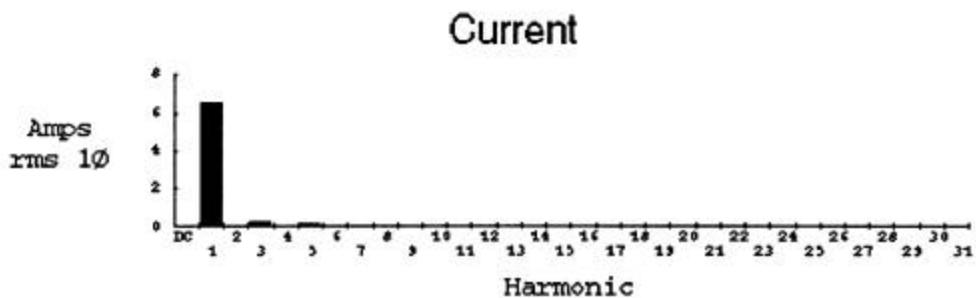
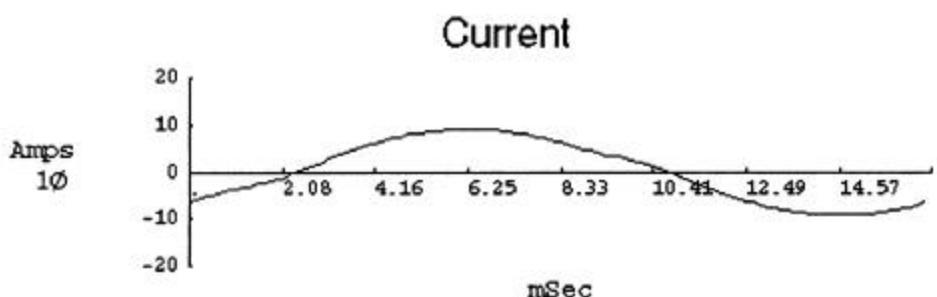
Model - Kenmore S.No. 110.82980120 (1991)

Ratings - 120V, 10A

Spin Cycle

Low Voltage Condition

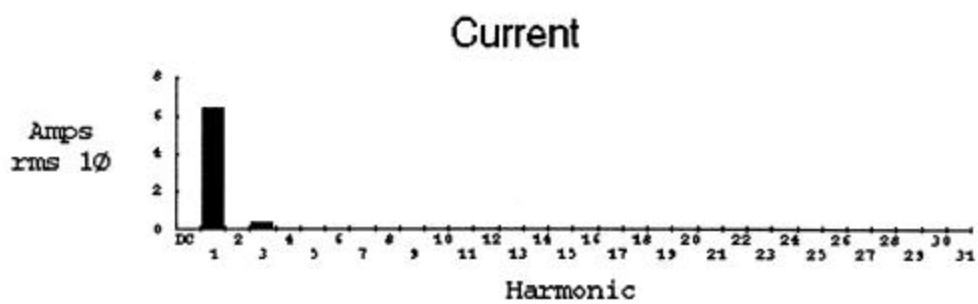
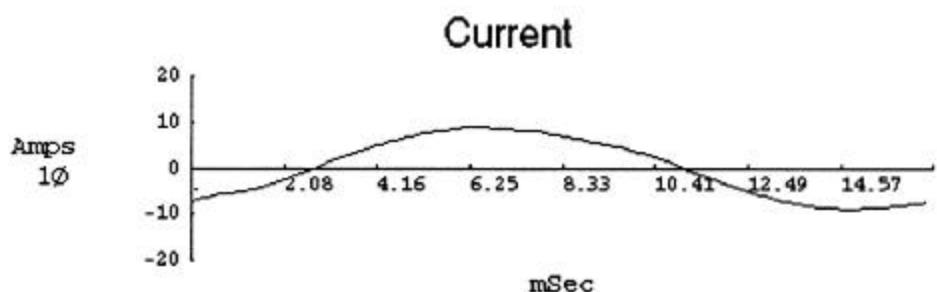
		Voltage	Current
Frequency	60.04	RMS	103.53
Power		Peak	145.16
KW	0.45	DC Offset	0.09
KVA	0.68	Crest	1.4
KVAR	0.51	THD Rms	1.28
Peak KW	1.17	THD Fund	1.28
Phase	49° lag	HRMS	1.33
Total PF	0.66	KFactor	0.35
DPF	0.65		1.04



Washing Machine
Model - Matag LAT8005AAE
Ratings - 120V, 7A (Yr - 1996)

Normal Voltage Condition

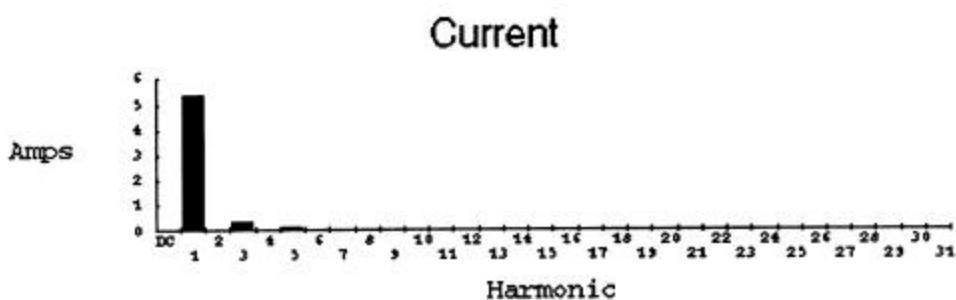
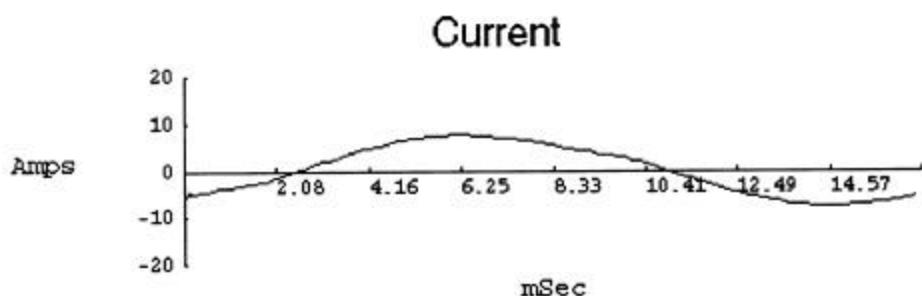
		Voltage	Current
Frequency	60.04	RMS	121.33
Power		Peak	170.59
KW	0.42	DC Offset	0.04
KVA	0.79	Crest	1.41
KVAR	0.66	THD Rms	2.03
Peak KW	1.30	THD Fund	2.03
Phase	58° lag	HRMS	2.46
Total PF	0.54	KFactor	1.03
DPF	0.53		



Washing Machine
Model - Matag LAT8005AAE
Ratings - 120V, 7A (Yr - 1996)

Low Voltage Condition

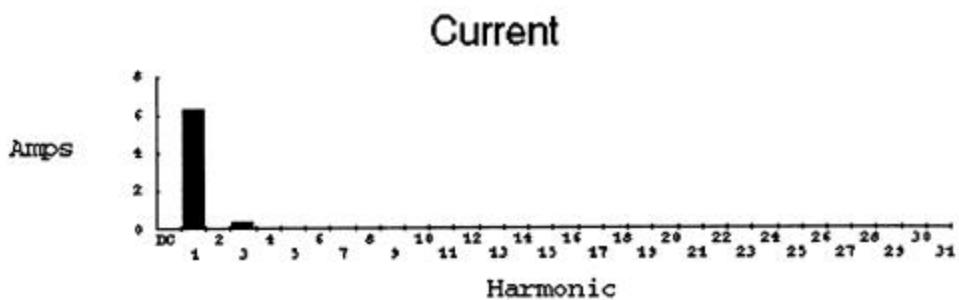
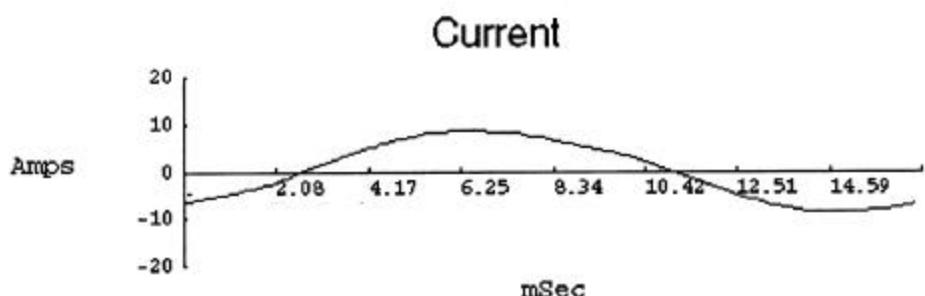
			Voltage	Current
Frequency	60.05	RMS	108.37	5.48
Power		Peak	152.20	7.78
KW	0.36	DC Offset	0.11	0.02
KVA	0.59	Crest	1.4	1.42
KVAR	0.46	THD Rms	1.91	6.43
Peak KW	1.03	THD Fund	1.91	6.44
Phase	53° lag	HRMS	2.07	0.35
Total PF	0.60	KFactor	1.04	
DPF	0.61			



Washing Machine
Model - Matag LAT8005AAE
Ratings - 120V, 7A (Yr - 1996)

Spin Cycle
Normal Voltage Condition

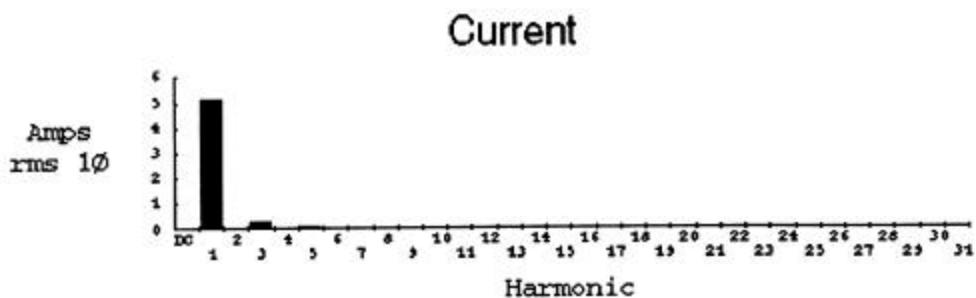
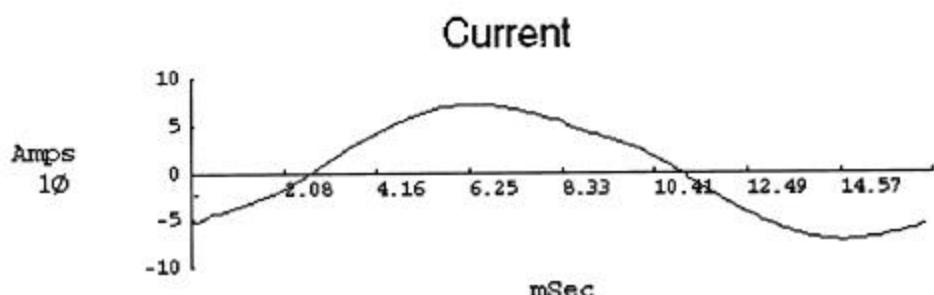
		Voltage	Current
Frequency	59.98	RMS	119.75
Power		Peak	168.29
KW	0.42	DC Offset	0.15
KVA	0.75	Crest	1.41
KVAR	0.62	THD Rms	1.95
Peak KW	1.26	THD Fund	1.95
Phase	56° lag	HRMS	2.33
Total PF	0.56	KFactor	1.03
DPF	0.56		



Washing Machine
Model - Matag LAT8005AAE
Ratings - 120V, 7A (Yr - 1996)

Spin Cycle
Low voltage condition

			Voltage	Current
Frequency	60.04	RMS	107.84	5.15
Power		Peak	151.46	7.40
KW	0.32	DC Offset	0.08	-0.02
KVA	0.55	Crest	1.4	1.44
KVAR	0.45	THD Rms	1.94	6.49
Peak KW	0.96	THD Fund	1.94	6.50
Phase	55° lag	HRMS	2.09	0.33
Total PF	0.58	KFactor	1.04	
DPF	0.58			

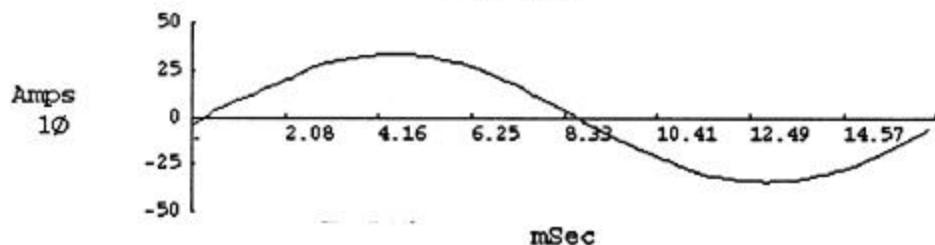


Clothes Dryer
Model - Kenmore (S. No. 110.86983110)
Ratings - 240V, 27A

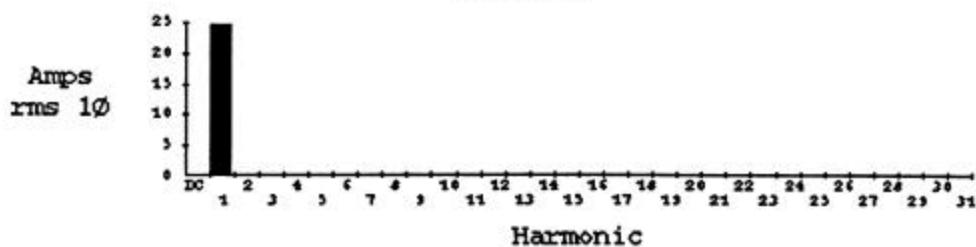
Normal Voltage Condition

		Voltage	Current
Frequency	60.04	RMS	234.5
Power		Peak	330.2
KW	5.75	DC Offset	0.1
KVA	5.80	Crest	1.41
KVAR	0.71	THD Rms	1.52
Peak KW	11.48	THD Fund	1.52
Phase	7° lag	HRMS	3.6
Total PF	0.99	KFactor	1.02
DPF	0.99		

Current



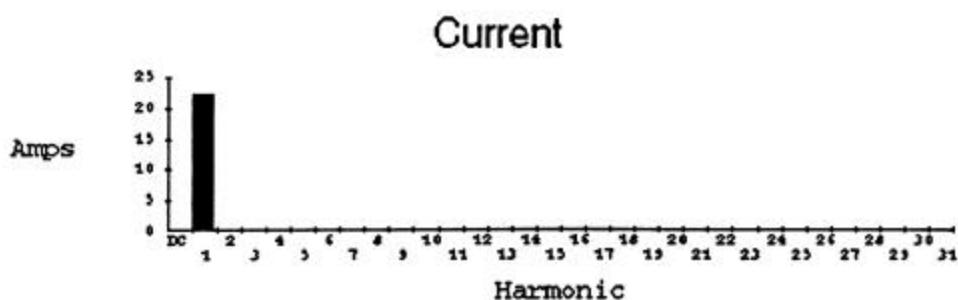
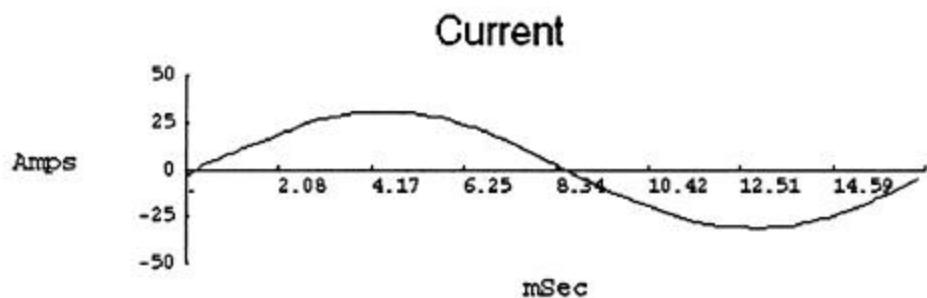
Current



Clothes Dryer
Model - Kenmore (S. No. 110.86983110)
Ratings - 240V, 27A

Low Voltage Condition

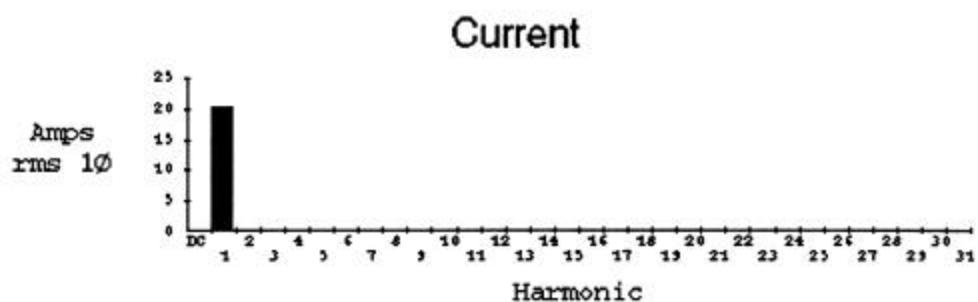
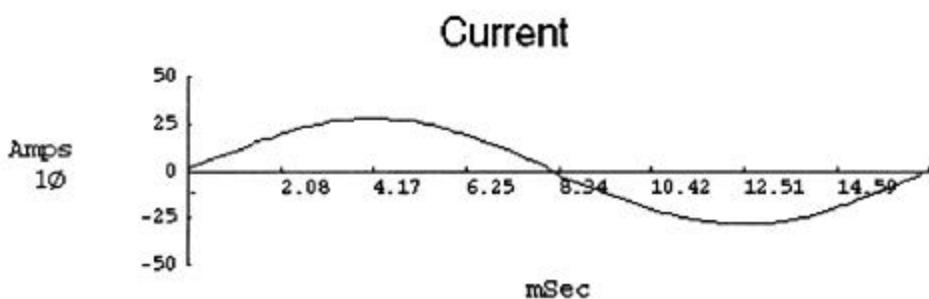
		Voltage	Current
Frequency	59.98	RMS	208.1
Power		Peak	31.69
KW	4.66	DC Offset	0.1
KVA	4.68	Crest	1.41
KVAR	0.52	THD Rms	1.48
Peak KW	9.28	THD Fund	1.48
Phase	6° lag	HRMS	3.1
Total PF	0.99	KFactor	1.02
DPF	0.99		



Clothes Dryer
Model - Matag LAT8005AAE
Ratings - 240V, 5.6KW (Yr - 1996)

Normal Voltage Condition

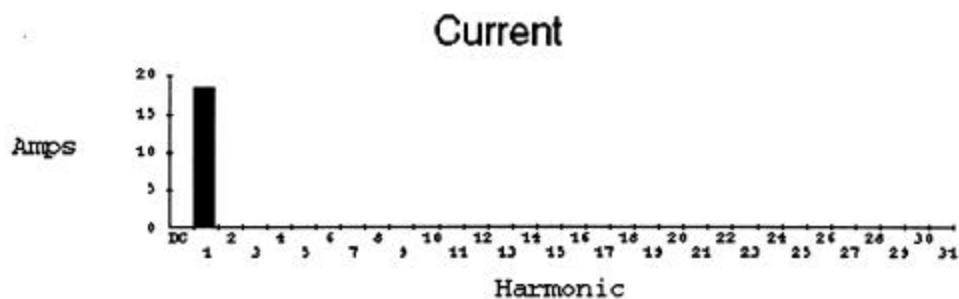
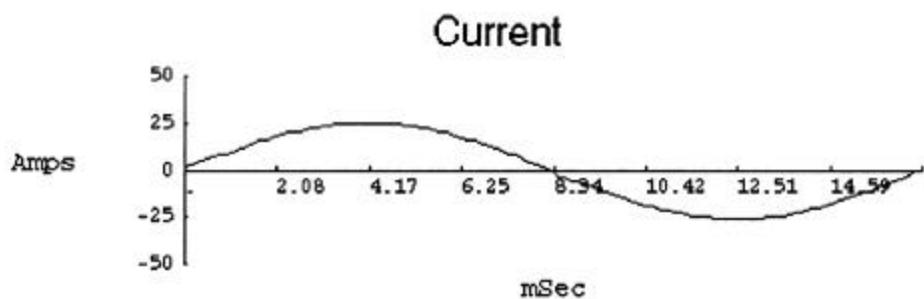
		Voltage	Current
Frequency	59.98	RMS	20.30
Power		Peak	28.72
KW	4.81	DC Offset	-0.22
KVA	4.81	Crest	1.41
KVAR	0.06	THD Rms	2.04
Peak KW	9.67	THD Fund	2.04
Phase	1° lead	HRMS	4.7
Total PF	1.00	KFactor	0.41
DPF	1.00		



Clothes Dryer
Model - Matag LAT8005AAE
Ratings - 240V, 5.6KW (Yr - 1996)

Low Voltage Condition

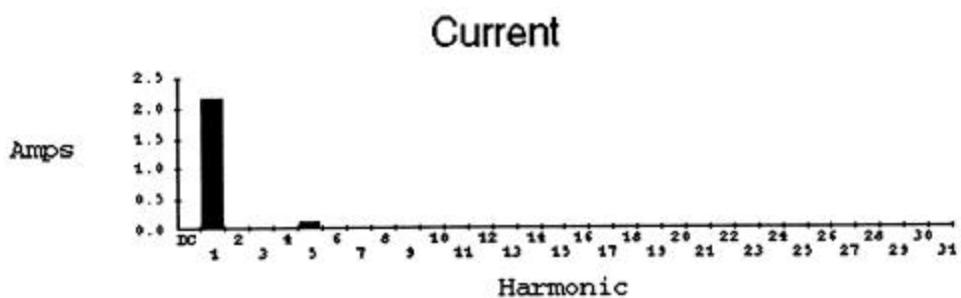
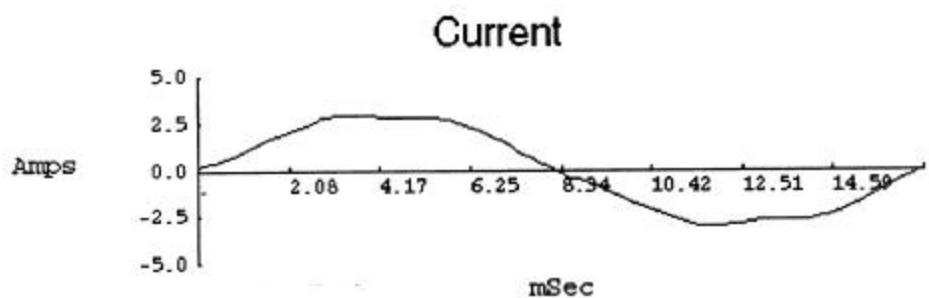
		Voltage	Current
Frequency	59.98	RMS	216.5
Power		Peak	18.58
KW	4.02	DC Offset	25.96
KVA	4.02	Crest	-0.21
KVAR	0.05	THD Rms	1.40
Peak KW	7.98	THD Fund	2.01
Phase	1° lead	HRMS	2.01
Total PF	1.00	KFactor	0.37
DPF	1.00		



Refrigerator
Model - Kenmore S.No. 106.9630580 (1993)
Ratings - 115V, 6.5A

Normal Voltage Condition

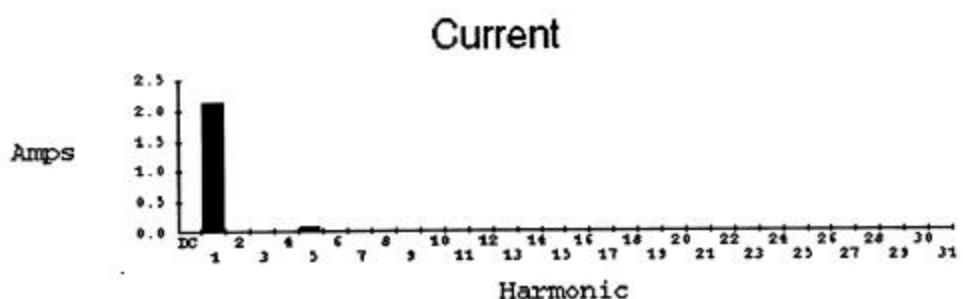
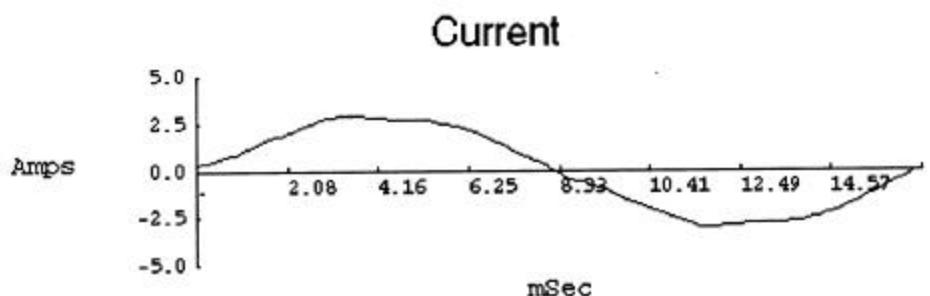
		Voltage	Current
Frequency	59.98	RMS	118.76
Power		Peak	167.21
KW	0.26	DC Offset	0.08
KVA	0.26	Crest	1.41
KVAR	0.00	THD Rms	1.44
Peak KW	0.50	THD Fund	1.44
Phase	1° lag	HRMS	1.72
Total PF	1.00	KFactor	0.13
DPF	1.00		1.10



Refrigerator
Model - Kenmore S.No. 106.9630580 (1993)
Ratings - 115V, 6.5A

Low Voltage Condition

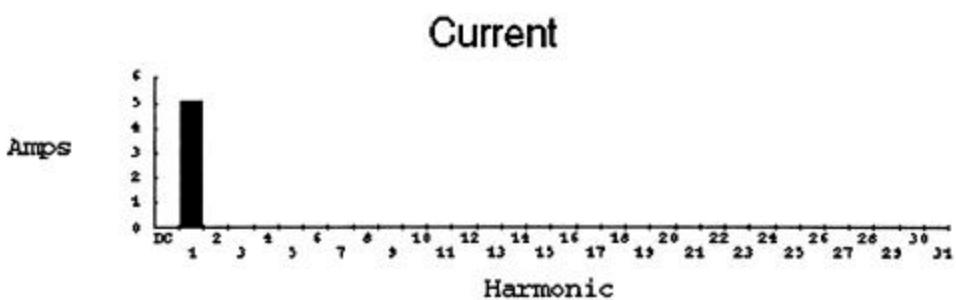
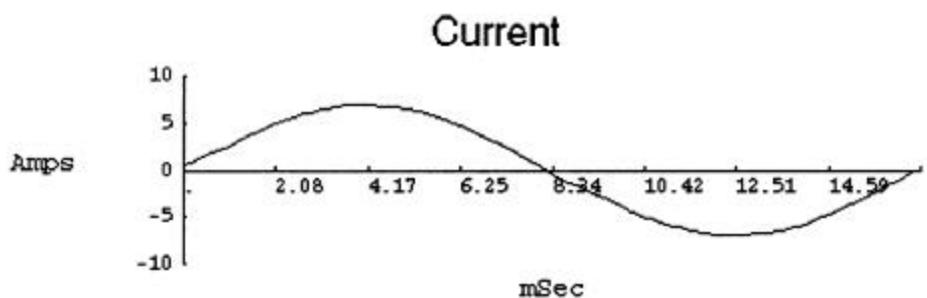
		Voltage	Current
Frequency	60.04	RMS	106.21
Power		Peak	149.52
Watts	227.63	DC Offset	0.01
VA	227.75	Crest	1.41
Vars	2.41	THD Rms	1.51
Peak W	447.42	THD Fund	1.51
Phase	1° lead	HRMS	1.60
Total PF	1.00	KFactor	0.10
DPF	1.00		1.08



Refrigerator
Model - Kitchen Aid KSRS27QAAL10
Ratings - 115V, 6.5A (Yr - 1994)

Normal Voltage Condition

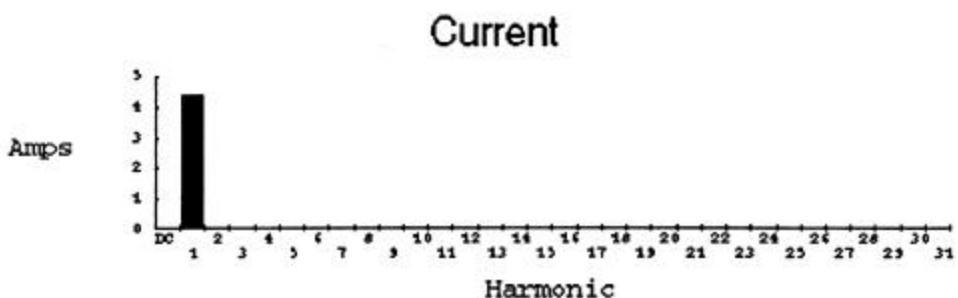
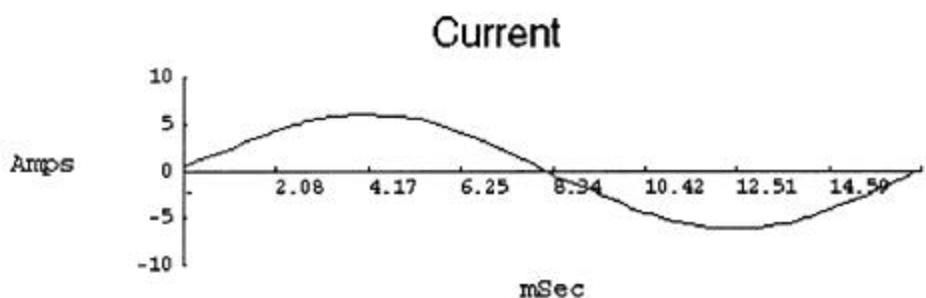
		Voltage	Current
Frequency	59.98	RMS	120.88
Power		Peak	170.03
KW	0.61	DC Offset	0.13
KVA	0.61	Crest	1.41
KVAR	0.02	THD Rms	2.05
Peak KW	1.20	THD Fund	1.96
Phase	2° lead	HRMS	2.48
Total PF	1.00	KFactor	1.02
DPF	1.00		



Refrigerator
Model - Kitchen Aid KSRS27QAAL10
Ratings - 115V, 6.5A (Yr - 1994)

Low Voltage Condition

			Voltage	Current
Frequency	59.98	RMS	107.78	4.39
Power		Peak	151.66	6.17
KW	0.47	DC Offset	0.13	-0.02
KVA	0.47	Crest	1.41	1.41
KVAR	0.02	THD Rms	2.07	1.93
Peak KW	0.94	THD Fund	2.08	1.93
Phase	2° lead	HRMS	2.24	0.08
Total PF	1.00	KFactor	1.02	
DPF	1.00			



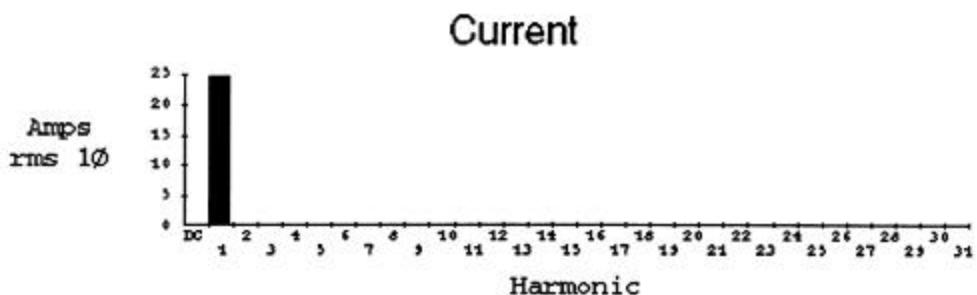
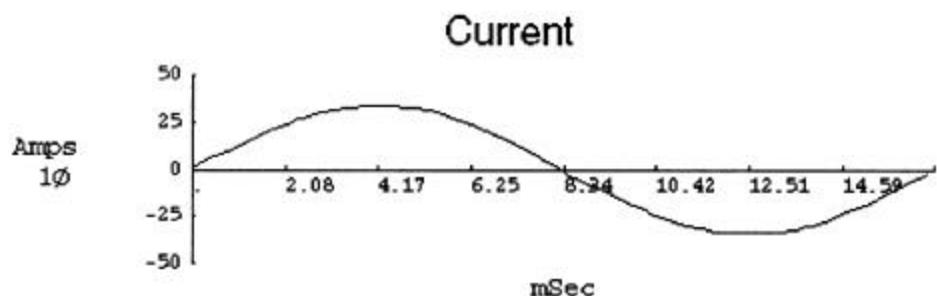
Oven

Model - Kitchen Aid KEBS207YAL

Ratings - 240V, 6.1KW (Yr - 1994)

Normal Voltage Condition

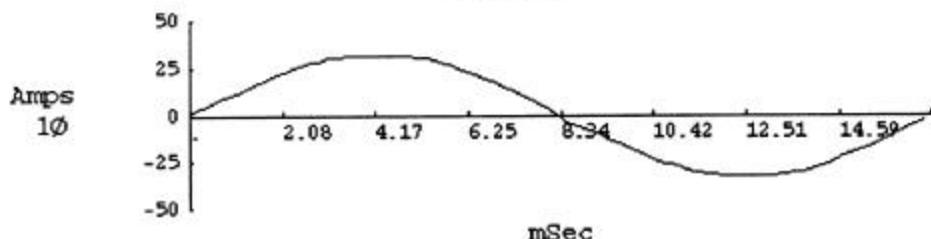
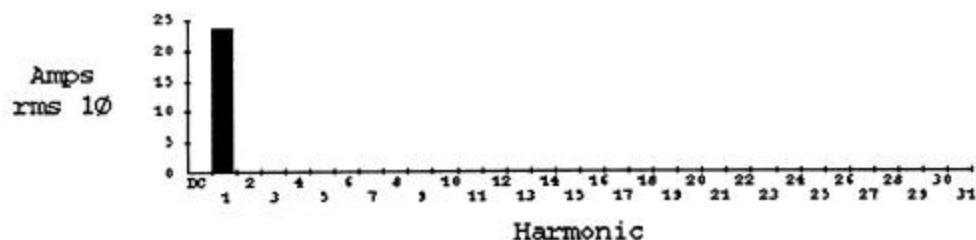
		Voltage	Current
Frequency	59.98	RMS	235.0
Power		Peak	331.0
KW	5.81	DC Offset	0.2
KVA	5.81	Crest	1.41
KVAR	0.07	THD Rms	1.94
Peak KW	11.52	THD Fund	1.94
Phase	1° lead	HRMS	4.6
Total PF	1.00	KFactor	1.03
DPF	1.00		



Oven**Model - Kitchen Aid KEBS207YAL****Ratings - 240V, 6.1KW (Yr - 1994)**

Low Voltage Condition

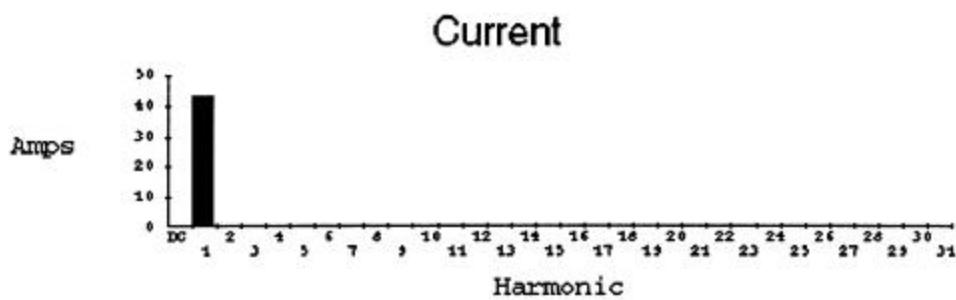
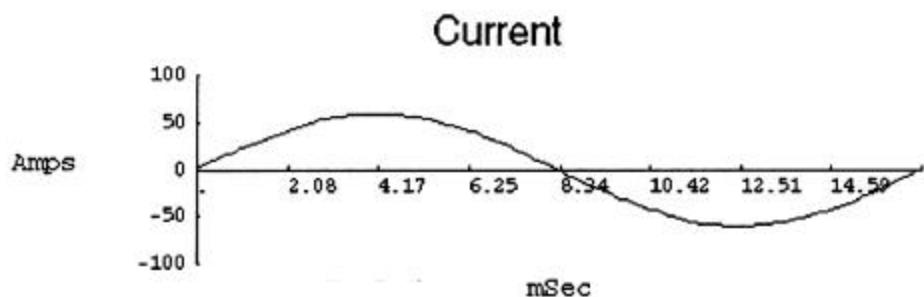
		Voltage	Current
Frequency	59.98	RMS	23.64
Power		Peak	33.19
KW	5.13	DC Offset	-0.22
KVA	5.13	Crest	1.40
KVAR	0.00	THD Rms	1.83
Peak KW	10.22	THD Fund	1.83
Phase	0° lag	HRMS	0.43
Total PF	1.00	KFactor	1.03
DPF	1.00		

Current**Current**

Heating Range
Model - Whirlpool RYE7760P2
Ratings - 240V, 11.9A

Normal Voltage Condition

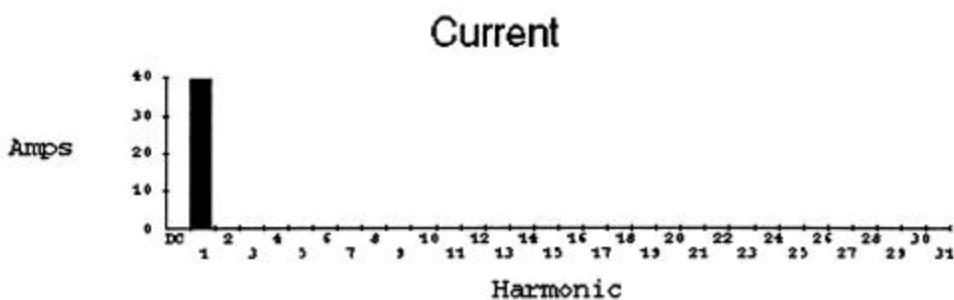
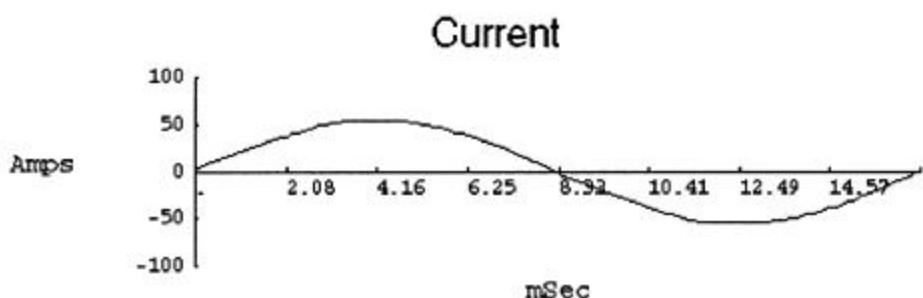
		Voltage	Current
Frequency	59.98	RMS	232.9
Power		Peak	327.6
KW	10.02	DC Offset	0.2
KVA	10.03	Crest	1.41
KVAR	0.13	THD Rms	1.54
Peak KW	19.93	THD Fund	1.54
Phase	1° lead	HRMS	3.6
Total PF	1.00	KFactor	1.01
DPF	1.00		



Heating Range
Model - Whirlpool RYE7760P2
Ratings - 240V, 11.9A

Low Voltage Condition

		Voltage	Current
Frequency	60.04	RMS	204.5
Power		Peak	287.8
KW	8.14	DC Offset	0.0
KVA	8.14	Crest	1.41
KVAR	0.10	THD Rms	1.55
Peak KW	16.16	THD Fund	1.55
Phase	1° lead	HRMS	3.2
Total PF	1.00	KFactor	1.01
DPF	1.00		

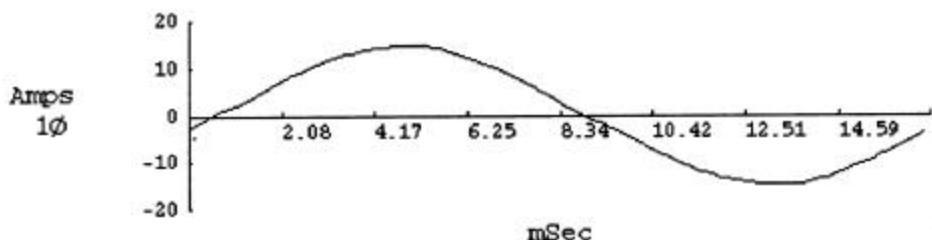


Dish Washer
Model - Kitchen Aid KUDI230BAL0
Ratings - 115V, 12.5A (Yr - 1994)

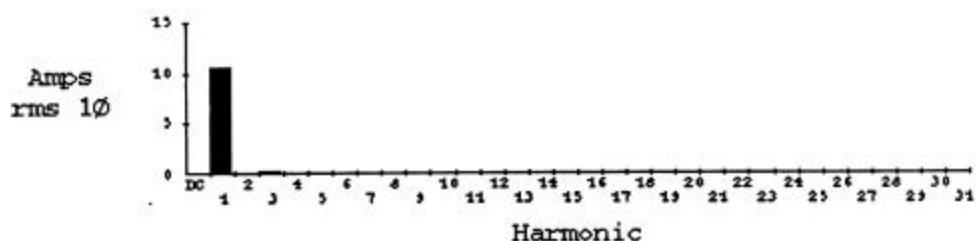
Low Voltage Condition

			Voltage	Current
Frequency	59.98	RMS	108.30	10.54
Power		Peak	152.33	15.17
KW	1.11	DC Offset	0.20	-0.01
KVA	1.14	Crest	1.41	1.44
KVAR	0.25	THD Rms	2.03	3.20
Peak KW	2.28	THD Fund	2.03	3.20
Phase	13° lag	HRMS	2.20	0.34
Total PF	0.98	KFactor	1.02	
DPF	0.98			

Current



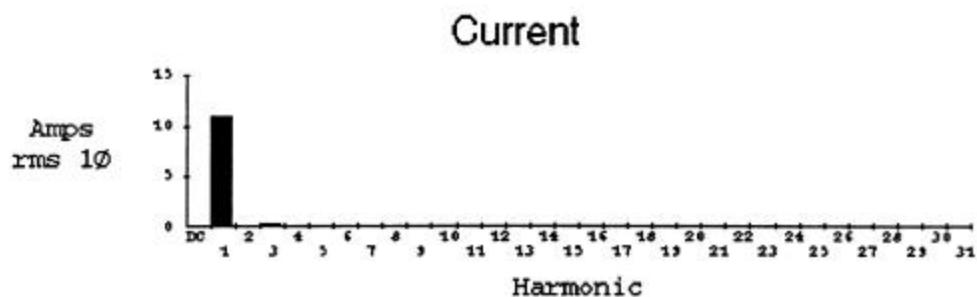
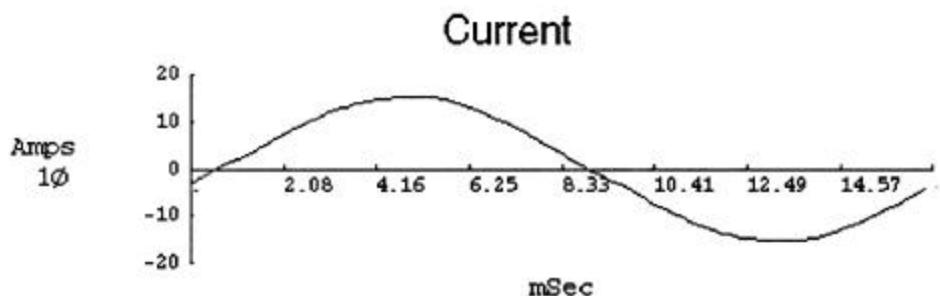
Current



Dish Washer
Model - Kitchen Aid KUDI230BAL0
Ratings - 115V, 12.5A (Yr - 1994)

Normal Voltage Condition

			Voltage	Current
Frequency	60.04	RMS	119.88	10.93
Power		Peak	168.45	15.73
KW	1.27	DC Offset	0.06	-0.03
KVA	1.31	Crest	1.41	1.44
KVAR	0.32	THD Rms	2.09	2.94
Peak KW	2.61	THD Fund	2.09	2.95
Phase	14° lag	HRMS	2.50	0.32
Total PF	0.97	KFactor	1.01	
DPF	0.97			





Appendix A.8

Electric Chargers



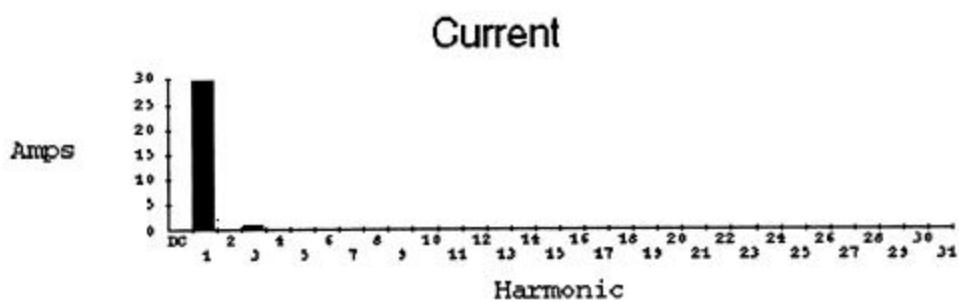
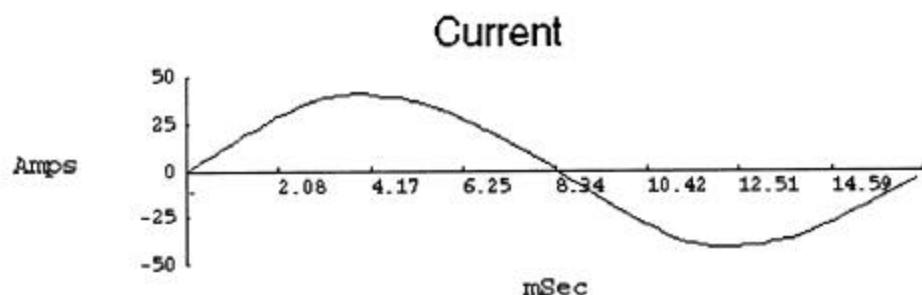
GM EV1

Model - Georgia Power #41909 (Yr. - 1999)

Charger Model WM200 # W2009721008R (Yr. - 1997)

Normal Voltage Condition at High Power

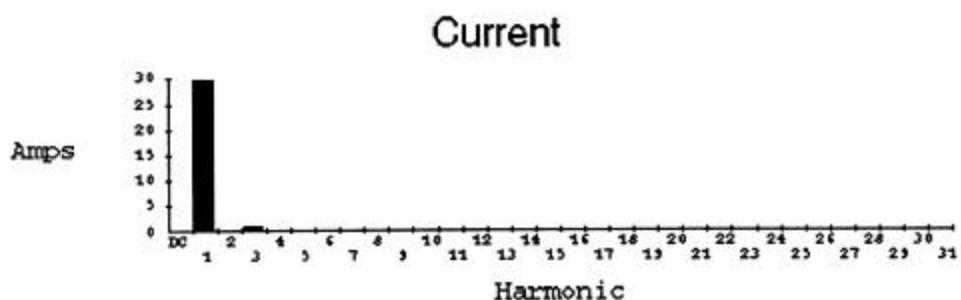
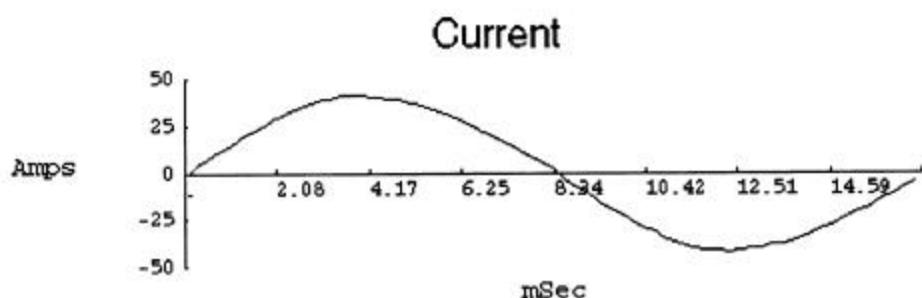
		Voltage	Current
Frequency	59.98	RMS	238.6
Power		Peak	334.0
KW	7.05	DC Offset	0.0
KVA	7.05	Crest	1.4
KVAR	0.09	THD Rms	1.94
Peak KW	14.17	THD Fund	1.94
Phase	1° lead	HRMS	4.6
Total PF	1.00	KFactor	1.03
DPF	1.00		



GM EV1**Model - Georgia Power #41909 (Yr. - 1999)****Charger Model WM200 # W2009721008R (Yr. - 1997)**

Low Voltage Condition at High Power

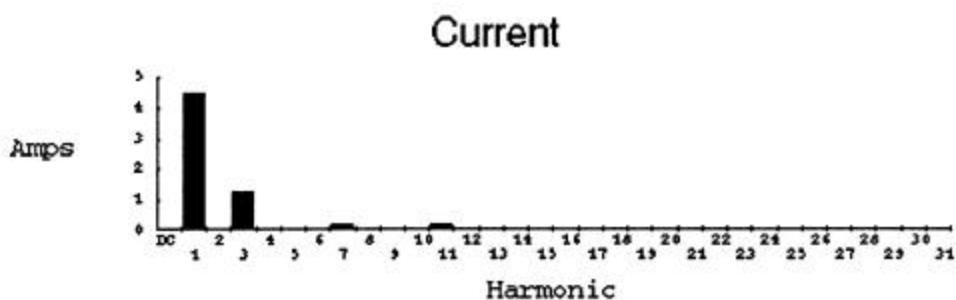
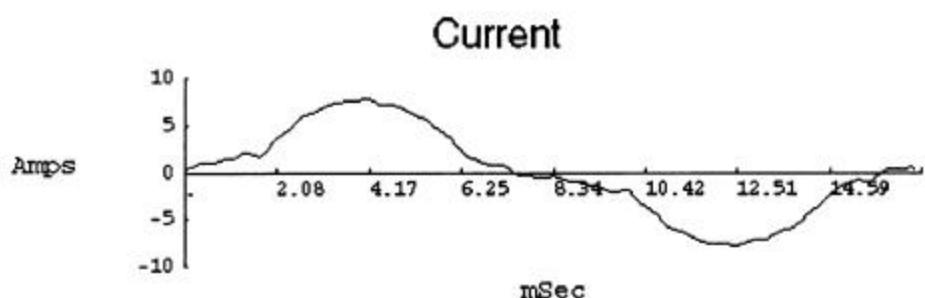
		Voltage	Current
Frequency	59.98	RMS	215.9
Power		Peak	42.44
KW	6.41	DC Offset	-0.20
KVA	6.41	Crest	1.43
KVAR	0.08	THD Rms	2.03
Peak KW	12.87	THD Fund	2.03
Phase	1° lead	HRMS	4.4
Total PF	1.00	KFactor	1.03
DPF	1.00		



GM EV1**Model - Georgia Power #41909 (Yr. - 1999)****Charger Model WM200 # W2009721008R (Yr. - 1997)**

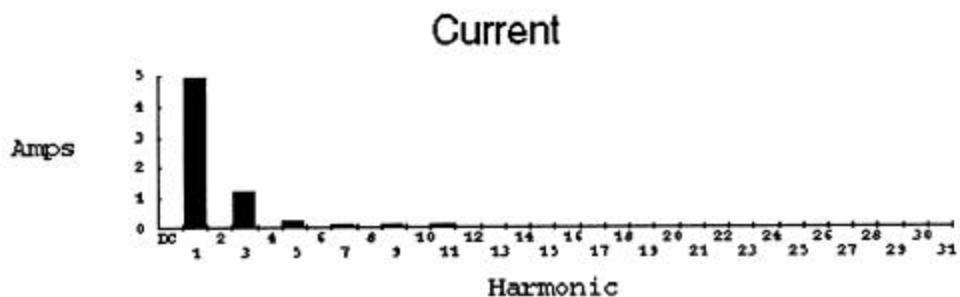
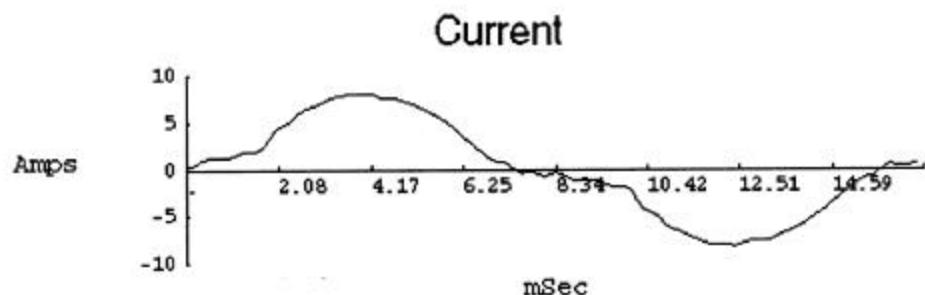
Normal Voltage Condition at Low Power

		Voltage	Current
Frequency	59.98	RMS	239.5
Power		Peak	335.1
KW	1.07	DC Offset	0.0
KVA	1.12	Crest	1.70
KVAR	0.13	THD Rms	1.70
Peak KW	2.65	THD Fund	1.70
Phase	7° lead	HRMS	4.1
Total PF	0.96	KFactor	2.16
DPF	0.99		



GM EV1**Model - Georgia Power #41909 (Yr. - 1999)****Charger Model WM200 # W2009721008R (Yr. - 1997)****Low Voltage Condition at Low Power**

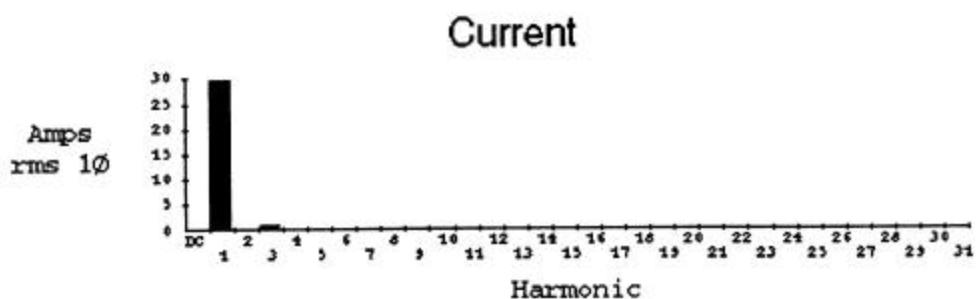
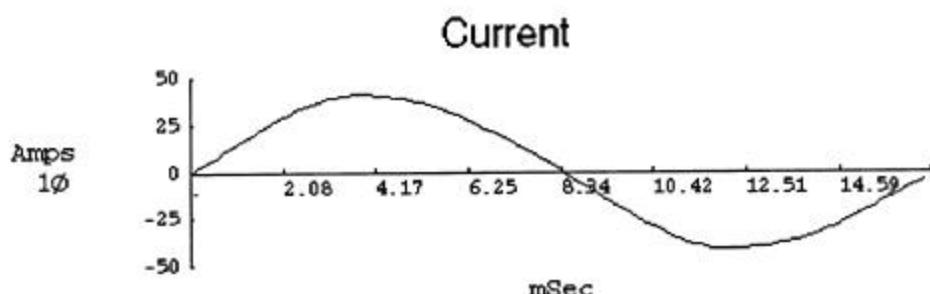
		Voltage	Current
Frequency	59.98	RMS	217.5
Power		Peak	304.3
KW	1.07	DC Offset	0.0
KVA	1.11	Crest	1.4
KVAR	0.12	THD Rms	1.74
Peak KW	2.54	THD Fund	1.74
Phase	6° lead	HRMS	3.8
Total PF	0.97	KFactor	1.23
DPF	0.99		1.88



GM S10**Model - Georgia Power #45836 (Yr. - 1998)****Charger Model WM200 # W2009721008R (Yr. - 1997)**

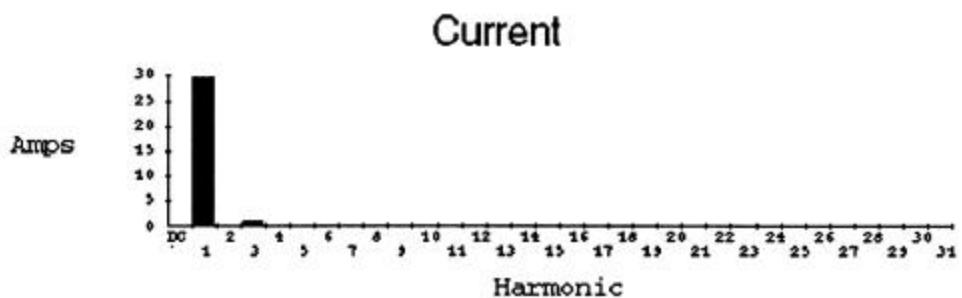
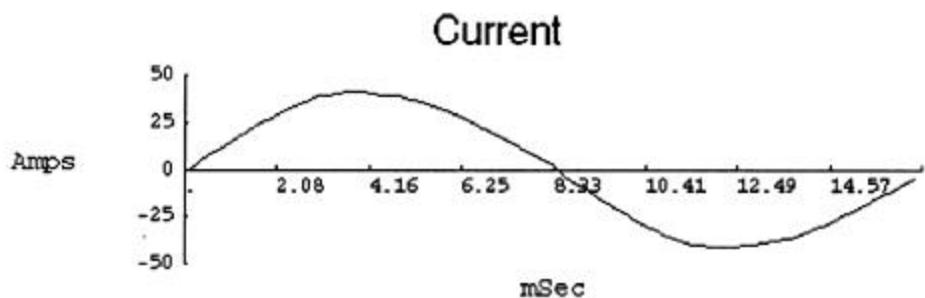
Normal Voltage Condition at High Power

		Voltage	Current
Frequency	59.98	RMS	240.2
Power		Peak	42.34
KW	7.11	DC Offset	0.0
KVA	7.12	Crest	1.43
KVAR	0.09	THD Rms	2.11
Peak KW	14.24	THD Fund	2.11
Phase	1° lead	HRMS	5.1
Total PF	1.00	KFactor	1.03
DPF	1.00		



GM S10**Model - Georgia Power #45836 (Yr. - 1998)****Charger Model WM200 # W2009721008R (Yr. - 1997)****Low Voltage Condition at High Power**

		Voltage	Current
Frequency	60.04	RMS	215.2
Power		Peak	299.9
KW	6.38	DC Offset	-0.4
KVA	6.38	Crest	1.39
KVAR	0.08	THD Rms	2.20
Peak KW	12.75	THD Fund	2.20
Phase	1° lead	HRMS	4.7
Total PF	1.00	KFactor	1.03
DPF	1.00		

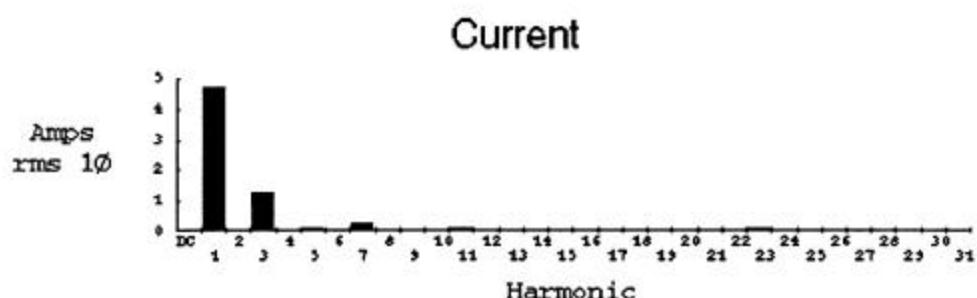
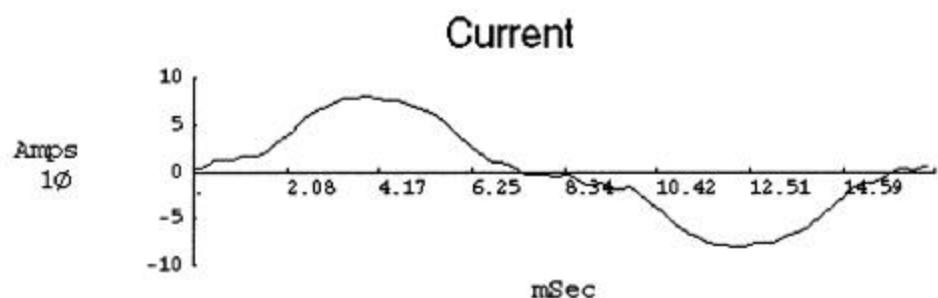


GM S10

Model - Georgia Power #45836 (Yr. - 1998)
Charger Model WM200 # W2009721008R (Yr. - 1997)

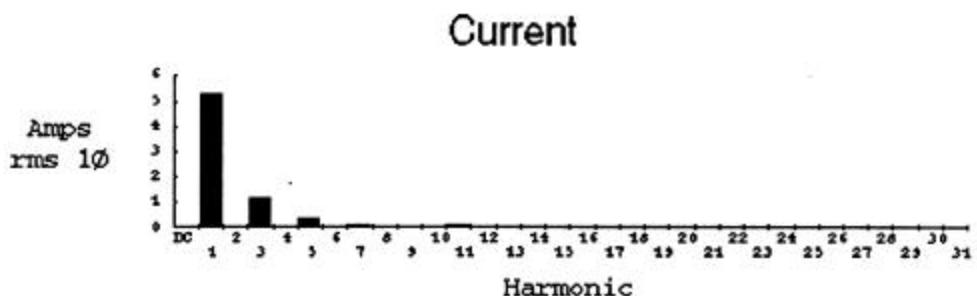
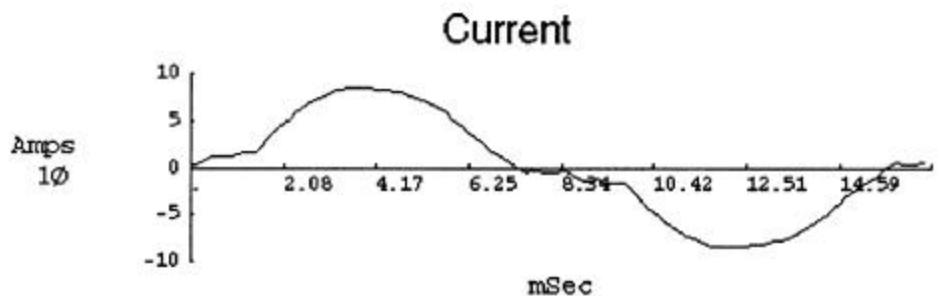
Normal Voltage Condition at Low Power

		Voltage	Current
Frequency	59.98	RMS	240.3
Power		Peak	334.4
KW	1.13	DC Offset	0.0
KVA	1.18	Crest	1.69
KVAR	0.14	THD Rms	2.16
Peak KW	2.77	THD Fund	2.16
Phase	7° lead	HRMS	5.2
Total PF	0.96	KFactor	1.97
DPF	0.99		



GM S10**Model - Georgia Power #45836 (Yr. - 1998)****Charger Model WM200 # W2009721008R (Yr. - 1997)****Low Voltage Condition at Low Power**

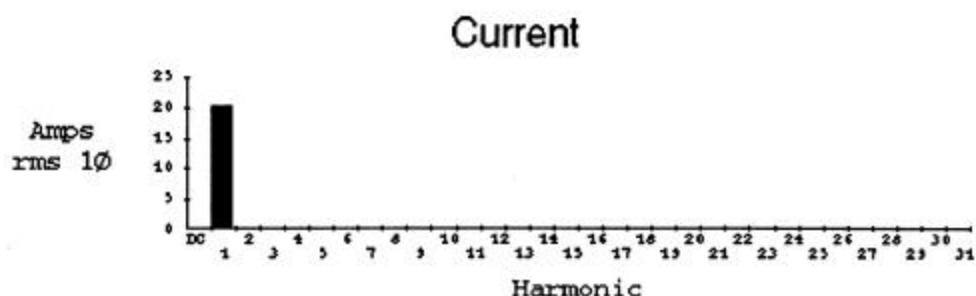
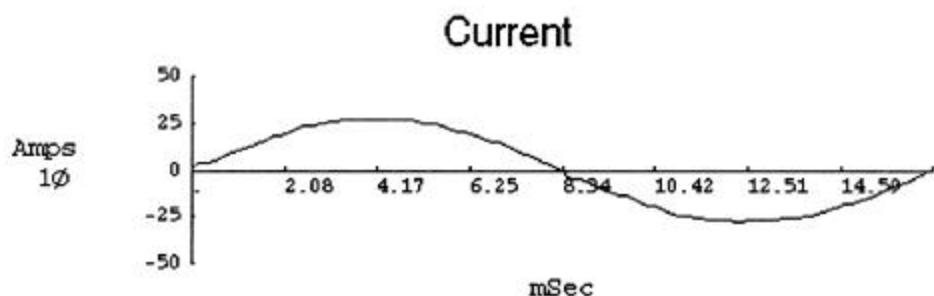
		Voltage	Current
Frequency	59.98	RMS	215.5
Power		Peak	299.6
KW	1.14	DC Offset	0.0
KVA	1.17	Crest	1.39
KVAR	0.13	THD Rms	2.22
Peak KW	2.64	THD Fund	23.56
Phase	6° lead	HRMS	4.8
Total PF	0.97	KFactor	1.28
DPF	0.99		1.79



Toyota RAV4**Model - Georgia Power #07816 (Yr. - 1998)****Charger Connecting Station SCI # 5394400-001 (Yr. - 1998)**

Normal Voltage Condition at High Power

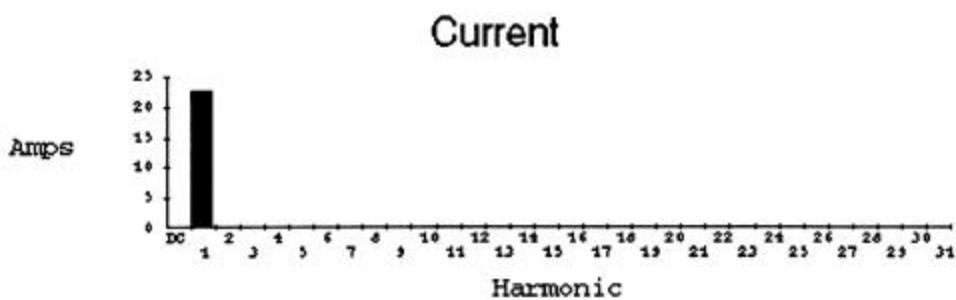
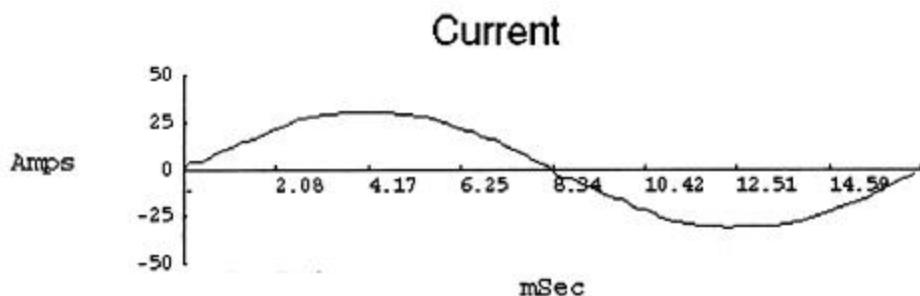
		Voltage	Current
Frequency	59.98	RMS	240.0
Power		Peak	335.1
KW	4.83	DC Offset	0.0
KVA	4.83	Crest	1.4
KVAR	0.06	THD Rms	2.13
Peak KW	9.53	THD Fund	2.13
Phase	1° lead	HRMS	5.1
Total PF	1.00	KFactor	1.16
DPF	1.00		



Toyota RAV4
Model - Georgia Power #07816 (Yr. - 1998)
Charger Connecting Station SCI # 5394400-001 (Yr. - 1998)

Low Voltage Condition at High Power

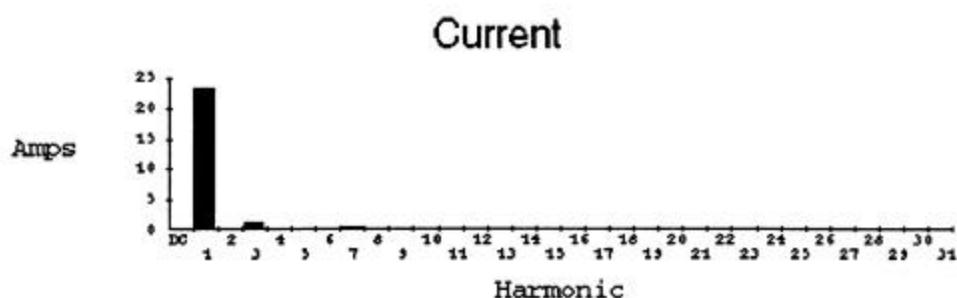
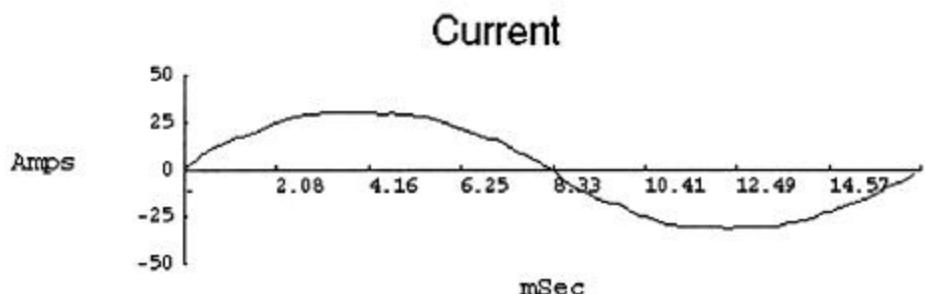
		Voltage	Current
Frequency	59.98	RMS	216.9
Power		Peak	302.5
KW	4.91	DC Offset	0.0
KVA	4.91	Crest	1.40
KVAR	0.06	THD Rms	2.20
Peak KW	9.67	THD Fund	2.20
Phase	1° lag	HRMS	4.8
Total PF	1.00	KFactor	1.15
DPF	1.00		



Ford Ranger**Model - Georgia Power #34802 (Yr. - 1998)****Charger Connecting Station SCI # 5394400-001 (Yr. - 1998)**

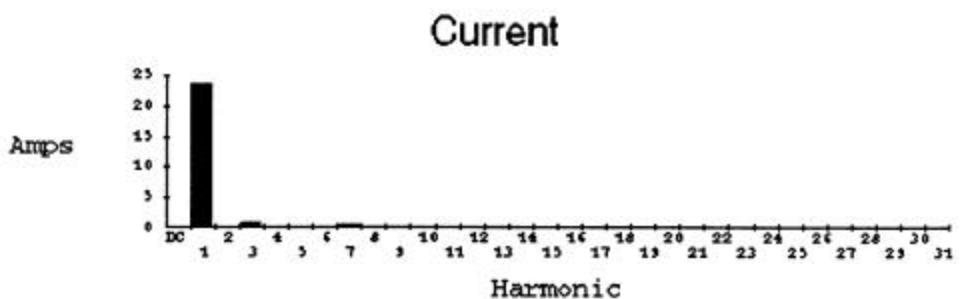
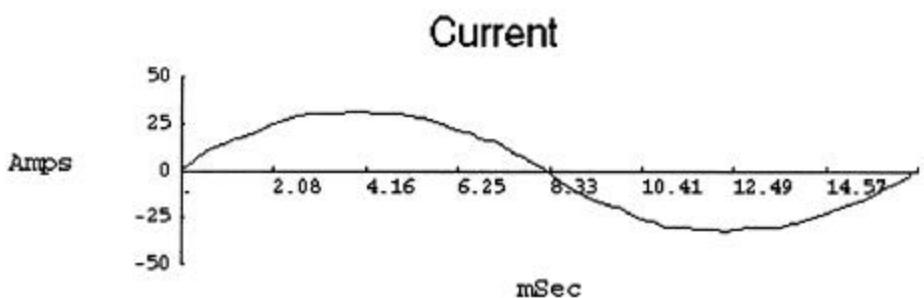
Normal Voltage Condition at High Power

		Voltage	Current
Frequency	60.04	RMS	240.0
Power		Peak	334.8
KW	5.61	DC Offset	-0.24
KVA	5.62	Crest	1.39
KVAR	0.28	THD Rms	2.25
Peak KW	10.74	THD Fund	2.25
Phase	3° lead	HRMS	5.25
Total PF	1.00	KFactor	5.26
DPF	1.00		1.23
			1.09



Ford Ranger**Model - Georgia Power #34802 (Yr. - 1998)****Charger Connecting Station SCI # 5394400-001 (Yr. - 1998)****Low Voltage Condition at High Power**

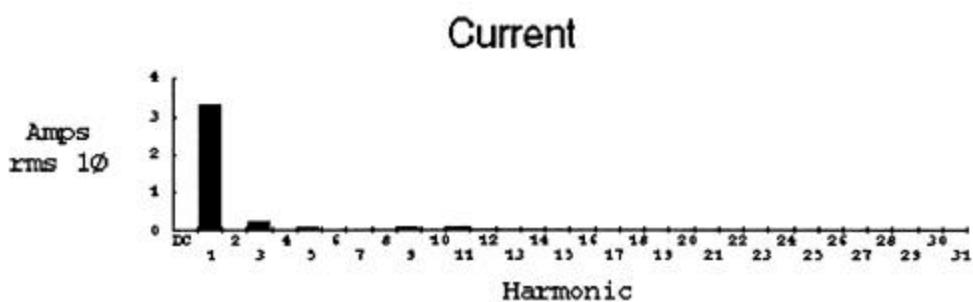
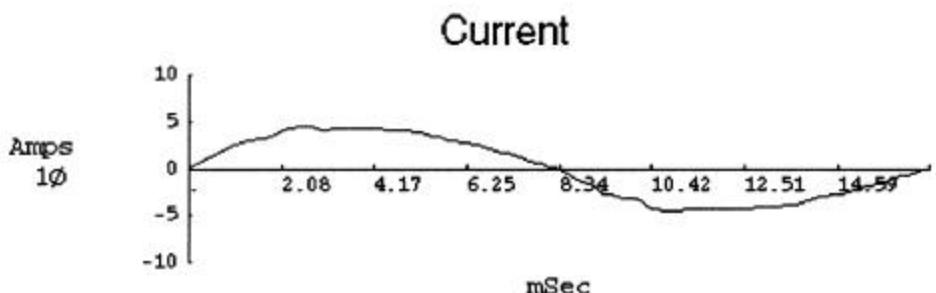
		Voltage	Current
Frequency	60.04	RMS	215.3
Power		Peak	32.55
KW	5.11	DC Offset	-0.24
KVA	5.12	Crest	1.37
KVAR	0.25	THD Rms	2.21
Peak KW	9.85	THD Fund	4.74
Phase	3° lead	HRMS	4.75
Total PF	1.00	KFactor	1.13
DPF	1.00		1.08



Ford Ranger**Model - Georgia Power #34802 (Yr. - 1998)****Charger Connecting Station SCI # 5394400-001 (Yr. - 1998)**

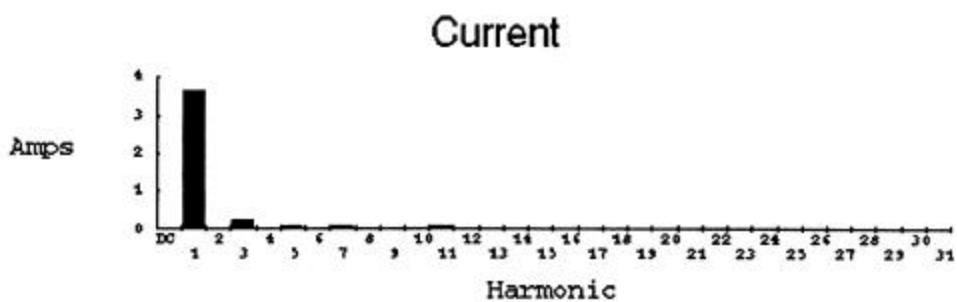
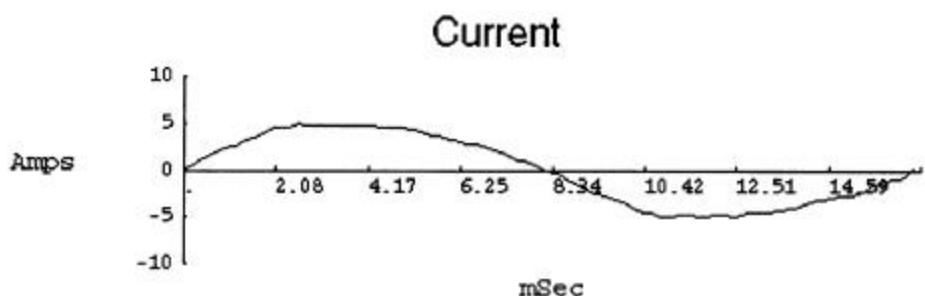
Normal Voltage Condition at Low Power

		Voltage	Current
Frequency	59.98	RMS	239.5
Power		Peak	335.6
KW	0.78	DC Offset	0.1
KVA	0.79	Crest	1.4
KVAR	0.11	THD Rms	1.73
Peak KW	1.51	THD Fund	1.73
Phase	8° lead	HRMS	4.1
Total PF	0.99	KFactor	1.36
DPF	0.99		



Ford Ranger**Model - Georgia Power #34802 (Yr. - 1998)****Charger Connecting Station SCI # 5394400-001 (Yr. - 1998)****Low Voltage Condition at Low Power**

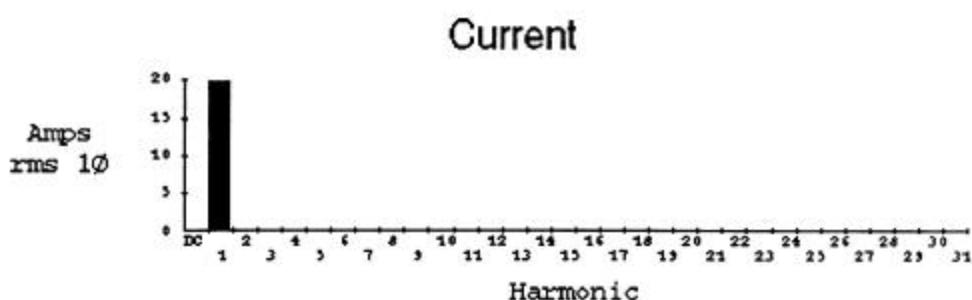
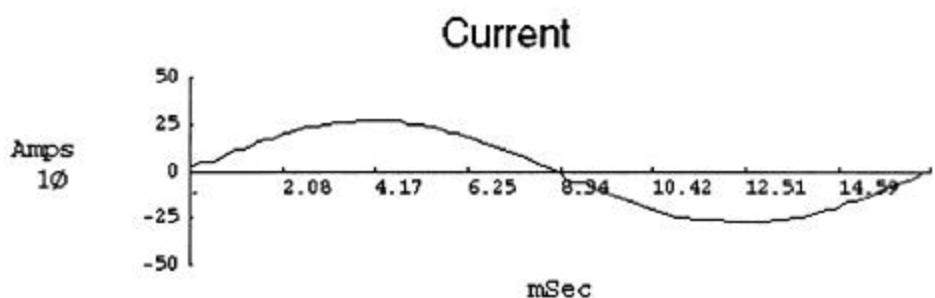
		Voltage	Current
Frequency	59.98	RMS	3.66
Power		Peak	5.03
KW	0.78	DC Offset	-0.02
KVA	0.79	Crest	1.38
KVAR	0.09	THD Rms	7.67
Peak KW	1.52	THD Fund	7.69
Phase	6° lead	HRMS	0.28
Total PF	0.99	KFactor	1.25
DPF	0.99		



Toyota RAV4
Model - Georgia Power #07828 (Yr. - 1998)
Charger Connecting Station EVI # TRO998007
Configuration No. EV 00617 (Yr. - 1998)

Normal Voltage Condition at High Power

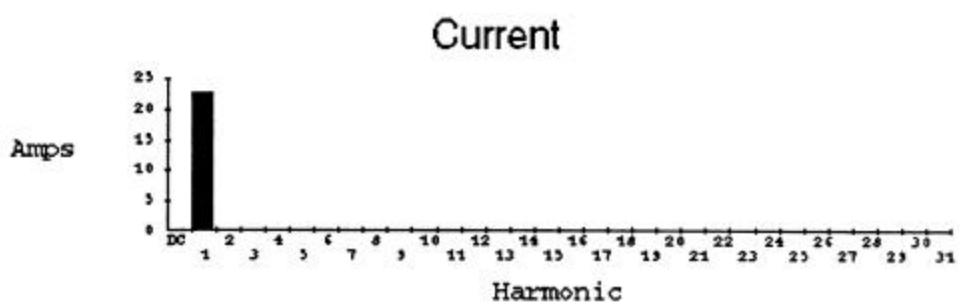
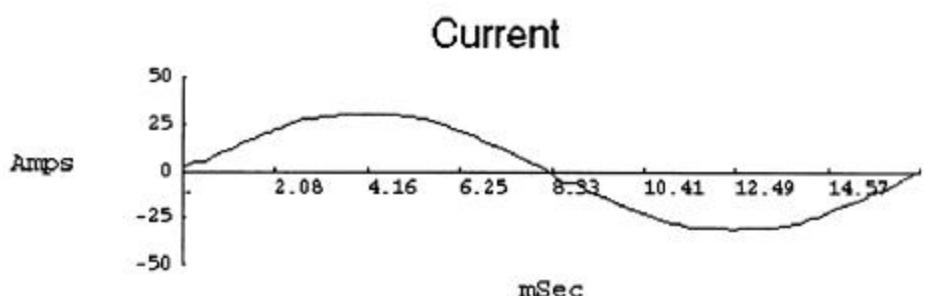
		Voltage	Current
Frequency	59.98	RMS	240.8
Power		Peak	332.3
KW	4.74	DC Offset	0.1
KVA	4.74	Crest	1.38
KVAR	0.23	THD Rms	1.97
Peak KW	9.24	THD Fund	1.97
Phase	3° lead	HRMS	4.7 0.46
Total PF	1.00	KFactor	1.15
DPF	1.00		



Toyota RAV4
Model - Georgia Power #07828 (Yr. - 1998)
Charger Connecting Station EVI # TRO998007
Configuration No. EV 00617 (Yr. - 1998)

Low Voltage Condition at High Power

		Voltage	Current
Frequency	60.05	RMS	215.6
Power		Peak	31.65
KW	4.89	DC Offset	-0.22
KVA	4.90	Crest	1.39
KVAR	0.06	THD Rms	1.98
Peak KW	9.48	THD Fund	2.40
Phase	1° lead	HRMS	4.3
Total PF	1.00	KFactor	0.55
DPF	1.00		1.16





Appendix A.9

Harmonic Data for Chargers



Harmonic Diversity Summary for Chargers

The phasor diagrams shown in Fig. 4 present the harmonic data for the chargers at the beginning of charging in a phasor diagram format as explained earlier for the appliances. The diversity effects arising due to the chargers is shown in Fig. 5 with the net current phasor arising due to all the chargers.

Figs. 6 and 7 illustrate the harmonic data at the end of charging in a phasor diagram data in a similar manner to the beginning of charging.

Phasor plots at beginning of charge

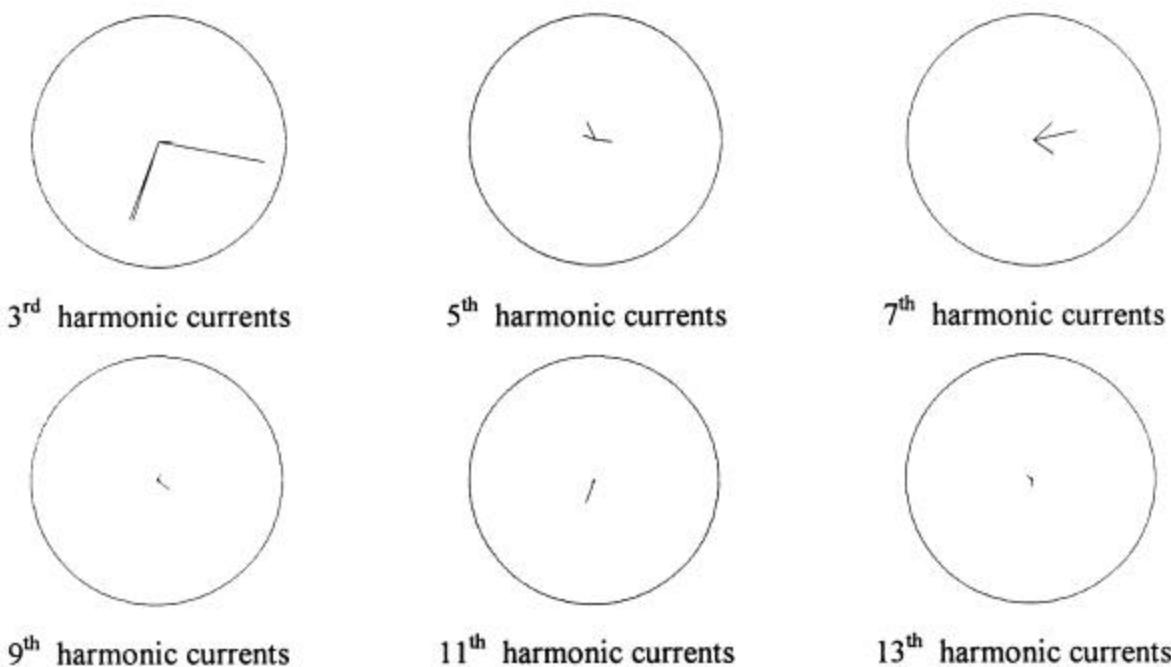
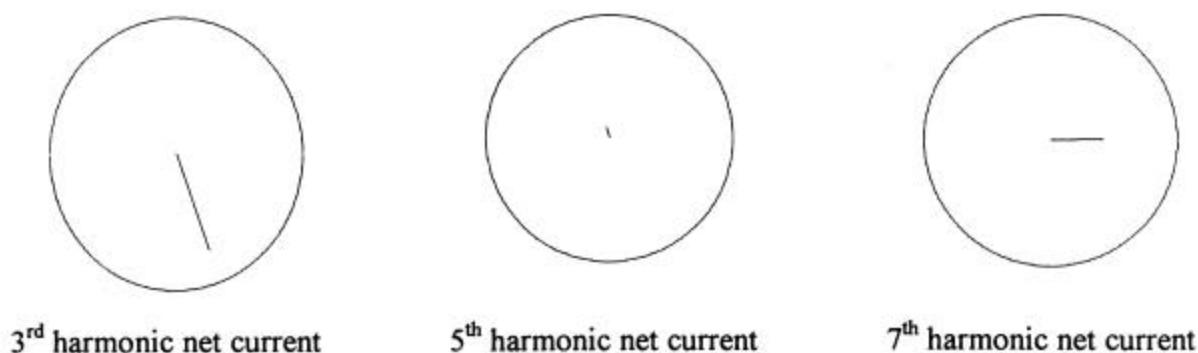
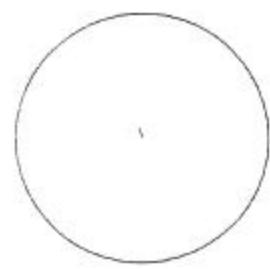
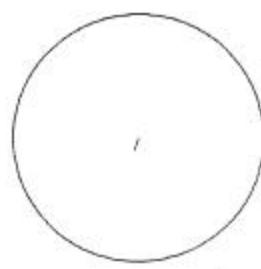


Figure 4: Phasor diagram of harmonic currents for all chargers on 1.25 A circles
(Beginning of charge)

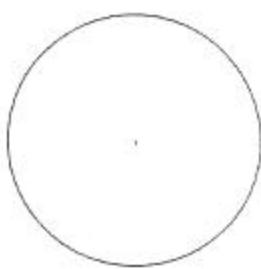




9th harmonic net current



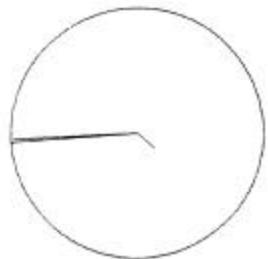
11th harmonic net current



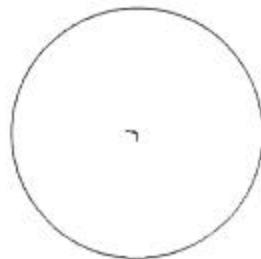
13th harmonic net current

Figure 5: Phasor sum of harmonic currents for all chargers on 2.5 A circles
(Beginning of charge)

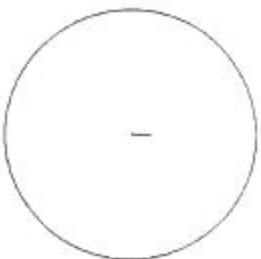
Phasor plots at end of charging



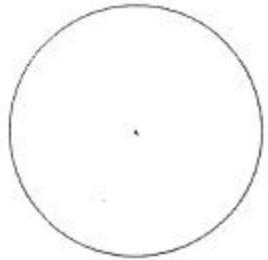
3rd harmonic currents



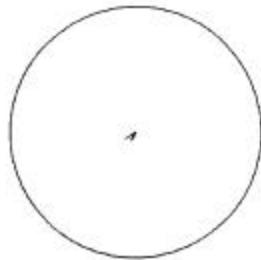
5th harmonic currents



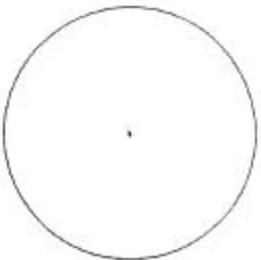
7th harmonic currents



9th harmonic currents

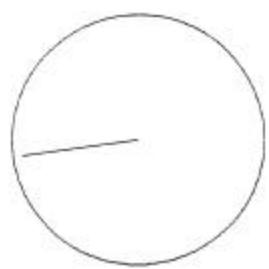


11th harmonic currents

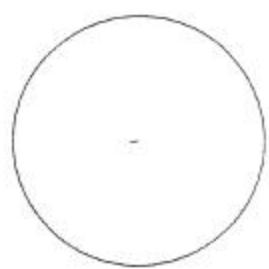


13th harmonic currents

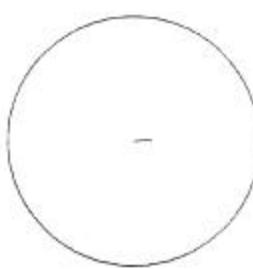
Figure 6: Phasor diagram of harmonic currents for all chargers on 1.25 A circles
(End of charge)



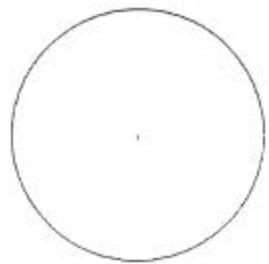
3rd harmonic net current



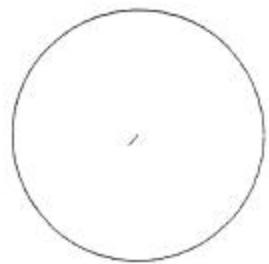
5th harmonic net current



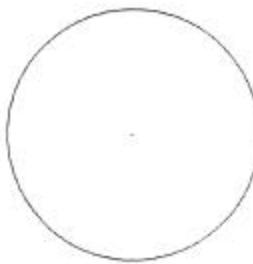
7th harmonic net current



9th harmonic net current



11th harmonic net current



13th harmonic net current

Figure 7: Phasor sum of harmonic currents for all chargers on 2.5 A circles
(End of charge)



Appendix A.10

Utility System Data



Utility System Data

Overhead Line Data

Distribution Transformer Parameters for Overhead Line

	Rated KVA	Rated voltage (KV)	%Z	X/R	NL (W)	LL (W)	No. of customers serviced
Utility "A"	37.5	12/0.24 4/0.24	1.75 1.75	1.032 1.032	*	*	15
Utility "B"	25	12/0.24 16/0.24 4/0.240	2.01 2.07 2.06	1.4 1.4 1.4	62 69 63	360 378 384	13
Utility "C"	25/50	12	1.2-1.4	*	*	*	*
Utility "D"	37.5	19.8	1.4	1.2	*	*	4
Utility "E"	50	36.5	2.17	1.58	*	*	4
Utility "F"	*	*	*	*	*	*	*

Note: * corresponds to data not provided

Transformer Loading Data

1. Utility "A":

Peak Loading: 50-55 KW

Minimum Loading : 15-20 KW

Load Profile : Peak loading from 6pm to 8pm dropping gradually to minimum loading from 3am to 5 am , rising to 40 KW from 7am to 9am dropping to 30 KW for late morning to early afternoon.

Service Line Data

	Service Length (ft)	Type of Conductor	Service Drops and conductor type
Utility "A"	100	4/0 AWAC	15 drops with mix of #2 Al and#4 Al Triplex of length 20" each
Utility "B"	80	#4 Al Triplex	*
Utility "C"	*	*	*
Utility "D"	75	1/0Al Triplex	*
Utility "E"	200	1/0 Al Triplex	*
Utility "F"	*	*	*

Note: * corresponds to data not provided

Underground Line Data

Distribution Transformer Parameters for Underground Line

	Rated KVA	Rated voltage (KV)	%Z	X/R	NL (W)	LL (W)	No. of customers serviced
Utility "A"	50	12/0.24 2.4/0.24	1.75 1.75	1.032 1.032	*	*	20
Utility "B"	25	12/0.24 16/0.24 4/0.240	1.87 1.87 2.01	1.4 1.4 1.4	87 94 64	380 387 394	6-8
Utility "C"	25/50	12	1.2-1.4	*	*	*	*
Utility "D"	50/75	19.8	1.8	1.5	*	*	5-7
Utility "E"	50	36.5	2.17	1.58	*	*	8
Utility "F"	*	*	*	*	*	*	*

Note: * corresponds to data not provided

Transformer Loading Data

1. Utility "A":

Peak Loading: 70-75 KW

Minimum Loading : 25 KW

Load Profile : Peak loading from 6pm to 8pm dropping gradually to minimum loading from 3am to 5 am , rising to 60 KW from 7am to 9am dropping to 45KW for late morning to early afternoon.

Service Line Data

	Service Length (ft)	Type of service line conductor	Service Drops and conductor type
Utility "A"	125-130	4/0 Al	20 drops with mix of #2 Al and 1/0 Al Triplex of length 20" each
Utility "B"	110	#2 CLP or 1/0 CLP	*
Utility "C"	*	*	*
Utility "D"	200	4/0Al UD Triplex	*
Utility "E"	200	1/0 Al Triplex	*
Utility "F"	*	*	*

Note: * corresponds to data not provided



Appendix B.1

HarmFlo+ Model Examples



HarmFLo+ Model Examples

Model File 1

!HarmFLo+ model for oven obtained from measurements taken

[OVEN1]

! Data came from file: oven.f41

NONLINEARLOAD

```
Name    =      %1      Bus    =      %2
KV     =    235.0E-3    KVA   =      5.81
DF     =      1.00      Leading =      Yes
FreqMult =    60
Table   =      {
    { 1,    24.73,      1},
    { 2,    0.04,    -127},
    { 3,    0.22,      111},
    { 4,    0.01,       57},
    { 5,    0.14,     124},
    { 6,    0.02,     169},
    { 7,    0.24,       46},
    { 8,    0.02,       80},
    { 9,    0.18,       72},
    {10,    0.03,    -101},
    {11,    0.08,       8},
    {12,    0.02,       68},
    {13,    0.08,       4},
    {14,    0.02,    -108},
    {15,    0.08,       15},
    {16,    0.03,     89},
    {17,    0.02,       30},
    {18,    0.02,    -70},
    {19,    0.04,       18},
    {20,    0.01,      56},
    {21,    0.04,       13},
    {22,    0.02,     131},
    {23,    0.02,       60},
    {24,    0.01,    -130},
    {25,    0.03,       44},
    {26,    0.01,     149},
    {27,    0.05,       41},
    {28,    0.03,       20},
    {29,    0.06,       23},
    {30,    0.01,     158},
    {31,    0.04,       11}
}
```

Model File 2

```
! HarmFlo+ model for Ford Ranger
[Ford]
NONLINEARLOAD
Name = %1          Bus = %2
KV = 240.0E-3      KVA = 5.62
DF = 1.00          Leading = Yes
FreqMult = 60
Table = {
    { 1,    23.40,     3},
    { 2,    0.02,    43},
    { 3,    1.07,   -11},
    { 4,    0.01,    79},
    { 5,    0.18,     -5},
    { 6,    0.02,    71},
    { 7,    0.45,     13},
    { 8,    0.01,    91},
    { 9,    0.16,   -35},
    {10,    0.01,    99},
    {11,    0.24,   -108},
    {12,    0.03,   147},
    {13,    0.09,   -84},
    {14,    0.03,    32},
    {15,    0.04,   -93},
    {16,    0.01,   135},
    {17,    0.05,     56},
    {18,    0.01,      8},
    {19,    0.05,   -20},
    {20,    0.01,   173},
    {21,    0.03,     86},
    {22,    0.01,     87},
    {23,    0.13,   -144},
    {24,    0.03,     95},
    {25,    0.11,   171},
    {26,    0.01,     84},
    {27,    0.04,   170},
    {28,    0.03,     97},
    {29,    0.02,   115},
    {30,    0.03,   -158},
    {31,    0.02,   -122}
}
```



Appendix B.2

Detailed Current Harmonic Comparison



Detailed Current Harmonic Comparison

Case 1(a)

Harmonic	X1 Measured (A)	X1 Simulated (A)
1	23.26	23.16
3	0.99	1.02
5	0.56	0.67
7	0.39	0.23
9	0.05	0.16
11	0.14	0.09
13	0.11	0.09
17	0.09	0.09
19	0.06	0.05
23	0.09	0.07
25	0.08	0.05

Case 1(b)

Harmonic	X1 Measured (A)	X1 Simulated (A)
1	4.09	5.92
3	1.89	3.21
5	1.13	2.04
7	0.55	1.03
9	0.18	0.33
11	0.08	0.21
13	0.12	0.28
17	0.03	0.10
19	0.02	0.05
23	0.01	0.04
25	0.01	0.01

Case 1(c)

Harmonic	X1 Measured (A)	X1 Simulated (A)	X3 Measured (A)	X3 Simulated (A)
1	27.31	27.27	23.46	23.15
3	1.06	2.42	1.03	1.02
5	1.66	0.59	0.56	0.67
7	0.36	0.56	0.41	0.23
9	0.21	0.28	0.04	0.16
11	0.21	0.21	0.11	0.09
13	0.06	0.17	0.10	0.09
17	0.10	0.13	0.11	0.09
19	0.08	0.02	0.03	0.05
23	0.10	0.10	0.08	0.07
25	0.08	0.04	0.08	0.05

Case 2(a)

Harmonic	X1 Measured (A)	X1 Simulated (A)	X3 Measured (A)	X3 Simulated (A)
1	26.39	25.56	30.49	30.69
3	0.37	0.23	0.30	0.29
5	0.47	0.14	0.31	0.18
7	0.26	0.25	0.43	0.30
9	0.16	0.19	0.18	0.23
11	0.02	0.08	0.08	0.09
13	0.10	0.08	0.06	0.09
17	0.03	0.02	0.06	0.02
19	0.04	0.04	0.04	0.04
23	0.04	0.02	0.03	0.02
25	0.03	0.03	0.04	0.03

Case 2(b)

Harmonic	X1 Measured (A)	X1 Simulated (A)	X3 Measured (A)	X3 Simulated (A)
1	40.56	40.57	34.00	35.67
3	0.48	0.39	0.32	0.33
5	0.57	0.22	0.34	0.21
7	0.39	0.39	0.45	0.33
9	0.21	0.17	0.20	0.22
11	0.01	0.08	0.07	0.09
13	0.08	0.10	0.06	0.10
17	0.02	0.02	0.03	0.02
19	0.04	0.04	0.07	0.04
23	0.02	0.02	0.03	0.02
25	0.03	0.03	0.03	0.03

Case 3(a)

Harmonic	X1Measured (A)	X1 Simulated (A)	X3 Measured (A)	X3 Simulated (A)
1	49.76	46.54	52.27	51.49
3	0.70	0.89	1.04	0.88
5	0.98	0.77	0.75	0.81
7	0.46	0.47	0.71	0.53
9	0.13	0.30	0.19	0.33
11	0.07	0.11	0.15	0.12
13	0.14	0.07	0.09	0.07
17	0.08	0.10	0.13	0.10
19	0.08	0.06	0.05	0.06
23	0.09	0.09	0.08	0.09
25	0.08	0.07	0.06	0.07

Case 3(b)

Harmonic	X1 Measured (A)	X1 Simulated (A)	X3 Measured (A)	X3 Simulated (A)
1	53.51	50.92	52.03	51.47
3	1.54	2.49	0.96	0.88
5	1.88	0.44	0.73	0.81
7	0.51	0.63	0.71	0.53
9	0.22	0.38	0.17	0.33
11	0.26	0.23	0.30	0.12
13	0.08	0.11	0.09	0.07
17	0.13	0.13	0.12	0.10
19	0.04	0.06	0.06	0.06
23	0.08	0.12	0.07	0.09
25	0.06	0.07	0.08	0.07

Case 3(c)

Harmonic	X1 Measured (A)	X1 Simulated (A)	X3 Measured (A)	X3 Simulated (A)
1	67.09	68.38	57.12	56.28
3	1.17	1.10	0.96	0.93
5	1.70	1.13	0.69	0.10
7	0.60	0.51	0.74	0.72
9	0.23	0.22	0.21	0.17
11	0.23	0.30	0.14	0.18
13	0.09	0.09	0.12	0.10
17	0.09	0.07	0.13	0.07
19	0.04	0.08	0.05	0.07
23	0.06	0.13	0.06	0.12
25	0.06	0.11	0.08	0.12



Appendix C.1

Compiler Summary



Siteldr is a PASCAL based program designed to aid SuperHarm in simulations of residential systems. **Siteldr** prompts the user for system information and then builds the text file input needed by SuperHarm.

The best way to explain the program is with an example. The example used is a residential system consisting of three families: the Robins, Jones and Smith families. The system is shown in Figure 1. The loads at each home and their connections are shown in Table A.

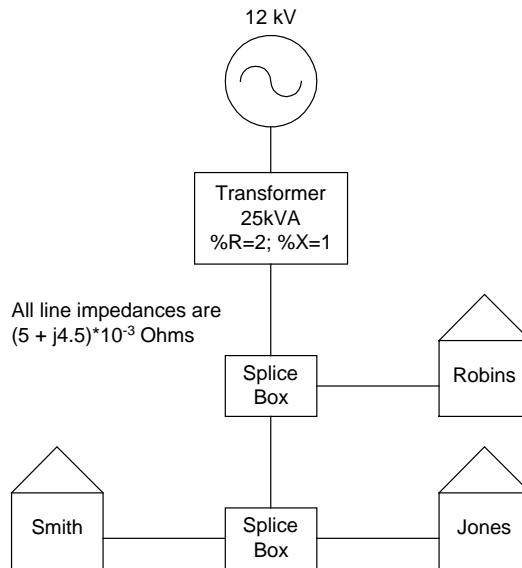


Fig. 1. Example System

Table A. Load Connections

Robins		Smith		Jones	
Appliance	Phase	Appliance	Phase	Appliance	Phase
16. Drill	A	1. Linear-2kW	AB	46. Vacuum	A
55. Honda	AB	12. Copier	B		
41. Stereo	B				

The number corresponding to each load (ie. 16 for the drill) is found in an Excel file included with the program. These numbers are used when selecting loads for the homes. The following section is the prompts encountered when using the program. Data entered by the user is in bold.

What would you like to name the output file? **demo.sha**

Please enter the following data for the distribution transformer:

KVA rating: **25**
 Primary Side Voltage (kV): **12**
 Reactance (%): **1**
 Resistance (%): **2**

How many homes are in this system? **3**
How many splice boxes are in this system? **2**

* In this section you will be asked to give names *
* to each home and splice box. This is for your *
* information. Please do not use duplicate names. *
* There is a 30 character maximum on the names. A *
* good example of a name for a home is the street *
* address.

Please press ENTER to continue.

Please give a descriptive name to home 1:
Robins

Please give a descriptive name to home 2:
Smith

Please give a descriptive name to home 3:
Jones

Please give a descriptive name to splice box 1:
Main_sbox

Please give a descriptive name to splice box 2:
Jones/Smith_sbox

* In this section you will be prompted for the *
* loads connected to each home and their phases. *
* Use the Load List provided with this program. *
* The List is also contained in the Excel file *
* Loads.xls. Use 0 to indicate that no more loads*
* are connected to a home.

Press ENTER to continue.

Please enter load 1 for home Robins: **16**
Please select the phase.

- 1) Phase A
 - 2) Phase B
 - 3) Phase AB
- 1**

Please enter load 2 for home Robins: **55**
Please select the phase.

- 1) Phase A
 - 2) Phase B
 - 3) Phase AB
- 3**

Please enter load 3 for home Robins: **41**

Please select the phase.

- 1) Phase A
- 2) Phase B
- 3) Phase AB

2

Please enter load 4 for home Robins: **0**

Please enter load 1 for home Smith: **1**

Please enter the size of the linear load (kW): **2**

Please select the phase.

- 1) Phase A
- 2) Phase B
- 3) Phase AB

3

Please enter load 2 for home Smith: **12**

Please select the phase.

- 1) Phase A
- 2) Phase B
- 3) Phase AB

2

Please enter load 3 for home Smith: **0**

Please enter load 1 for home Jones: **46**

Please select the phase.

- 1) Phase A
- 2) Phase B
- 3) Phase AB

1

Please enter load 2 for home Jones: **0**

* In the following section you will be prompted *
* for information concerning adjacencies. For each*
* home and splice box you will be given a list of *
* available nodes. Enter the integer *
* corresponding to the first connection and press *
* ENTER. You will then be prompted for the branch*
* reactance and resistance. The units are in *
* milli-Ohms.

Press ENTER to continue.

Select a node connected to Robins:

- | | |
|------------------------|----------------|
| 0) No more connections | 2) Smith |
| 3) Jones | 4) Main_sbox |
| 5) Jones/Smith_sbox | 6) Transformer |

4

For the branch that connects
Robins to Main_sbox:

Please enter the reactance (mOhms): **4.5**
Please enter the resistance (mOhms): **5**

Select a node connected to Robins:

- | | |
|------------------------|---------------------|
| 0) No more connections | 2) Smith |
| 3) Jones | 5) Jones/Smith_sbox |
| 6) Transformer | |
| 0 | |

Select a node connected to Smith:

- | | |
|------------------------|---------------------|
| 0) No more connections | 3) Jones |
| 4) Main_sbox | 5) Jones/Smith_sbox |
| 6) Transformer | |
| 5 | |

For the branch that connects
Smith to Jones/Smith_sbox:

Please enter the reactance (mOhms): **4.5**
Please enter the resistance (mOhms): **5**

Select a node connected to Smith:

- | | |
|------------------------|----------------|
| 0) No more connections | 3) Jones |
| 4) Main_sbox | 6) Transformer |
| 0 | |

Select a node connected to Jones:

- | | |
|------------------------|----------------|
| 0) No more connections | 4) Main_sbox |
| 5) Jones/Smith_sbox | 6) Transformer |
| 5 | |

For the branch that connects
Jones to Jones/Smith_sbox:

Please enter the reactance (mOhms): **4.5**
Please enter the resistance (mOhms): **5**

Select a node connected to Jones:

- | | |
|------------------------|--------------|
| 0) No more connections | 4) Main_sbox |
| 6) Transformer | |
| 0 | |

Select a node connected to Main_sbox:

- | | |
|------------------------|---------------------|
| 0) No more connections | 5) Jones/Smith_sbox |
| 6) Transformer | |
| 5 | |

For the branch that connects
Main_sbox to Jones/Smith_sbox:

Please enter the reactance (mOhms): **4.5**
Please enter the resistance (mOhms): **5**

Select a node connected to Main_sbox:

- | | |
|------------------------|----------------|
| 0) No more connections | 6) Transformer |
|------------------------|----------------|

6

For the branch that connects
Main_sbox to Transformer:

Please enter the reactance (mOhms): 4.5
Please enter the resistance (mOhms): 5

Select a node connected to Main_sbox:

- 0) No more connections
- 0

Select a node connected to Jones/Smith_sbox:

- 0) No more connections
- 6) Transformer
- 0

What title would you like to give this simulation? **3 Homes**

The output file demo.sha is now ready to be used as a SuperHarm input. The text file created by the above steps is shown below.

```
TITLE
TITLE1="3 Homes"

OPTIONS
IGNOREISLANDS = Yes
OPTIMALORDER = Yes

!VOLTAGE SOURCE STATEMENT
! Parameters:
!    1 - Name
!    2 - Output
!    3 - Magnitude (kV)

#library models.shl VS (Source, Prim, 120.000)

!END VOLTAGE SOURCE STATEMENT
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

!SPLIT PHASE DISTRIBUTION TRANSFORMER
! %X = 1.00E+00
! %R = 2.00E+00

TRANSFORMER

Name = Split_Phase
H.1 = Prim
H.2 = Ground
```

```

X.1      = pccA
X.2      = Ground
T.1      = Ground
T.2      = pccB
MVA     = 2.50E-02
kV.H    = 1.20E+01
kV.X    = 1.20E-01
kV.T    = 1.20E-01
%X.HX   = 1.20E+00
%X.HT   = 1.20E+00
%R.HX   = 3.00E+00
%R.HT   = 3.00E+00
%X.XT   = 8.00E-01
%R.XT   = 4.00E+00

!END SPLIT PHASE DISTRIBUTION TRANSFORMER
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

!IDEAL TRANSFORMERS-needed for homes with 240V loads
! Parameters:
!     1 - House Number

! For home Robins
#library models.shl IDLXFMR (1)

! For home Smith
#library models.shl IDLXFMR (2)

!END IDEAL TRANSFORMER STATEMENTS
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

!BRANCH STATEMENTS
! Parameters:
!     1 - From
!     2 - To
!     3 - Reactance (mOhm)
!     4 - Resistance (mOhm)

! For Robins to Main_sbox
#library models.shl BRNCH (h1, s1, 4.500, 5.000)

! For Smith to Jones/Smith_sbox
#library models.shl BRNCH (h2, s2, 4.500, 5.000)

```

```

! For Jones to Jones/Smith_sbox
#library models.shl BRNCH (h3, s2, 4.500, 5.000)

! For Main_sbox to Jones/Smith_sbox
#library models.shl BRNCH (s1, s2, 4.500, 5.000)

! For Main_sbox to Transformer
#library models.shl BRNCH (s1, pcc, 4.500, 5.000)

!END BRANCH STATEMENTS
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

!LOAD STATEMENTS
! Parameters:
!     All Except LLOAD          LLOAD
!     1 - Name                  1 - Size (kW)
!     2 - Bus                   2 - Name
!                             3 - Bus

! For home Robins

#library models.shl DRILL1      (ld1_1, h1A )
#library models.shl HONDA       (ld1_2, h1AB)
#library models.shl STEREO1     (ld1_3, h1B )

! For home Smith

#library models.shl LLOAD      (2.000, ld2_1, h2AB)
#library models.shl COPIER2    (ld2_2, h2B )

! For home Jones

#library models.shl VACUUM2    (ld3_1, h3A )
!END LOAD STATEMENTS

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

RETAIN CURRENTS = Yes

!NODE REFERENCES
! h1 Robins
! h2 Smith
! h3 Jones
! s1 Main_sbox
! s2 Jones/Smith_sbox
! pcc Transformer
.....

```

A list of available loads and their corresponding numbers referenced to in the program is shown below in Table C.1.A

Table C.1.A List of Available Loads

1	Linear Load	31	Mixer B
2	AC (Bottom)	32	Mixer B (Low)
3	AC (Top)	33	Monitor
4	Amplifier	34	Microwave
5	Cassette Player	35	Oven
6	CD Player A	36	Printer
7	CD Player B	37	Pump
8	Coffee Maker A	38	Range
9	Coffee Maker B	39	Satellite Dish
10	Computer A	40	Scanner
11	Computer B	41	Stereo
12	Copier	42	Toaster
13	Copier (Low Power)	43	Television A
14	Dimmer	44	Television B
15	Dishwasher	45	UPS
16	Drill	46	Vacuum
17	Dryer A	47	VCR A
18	Dryer B	48	VCR B
19	Electronic Ballast	49	Washer A
20	Refrigerator A	50	Washer B
21	Refrigerator B	51	Washer A (Spin)
22	Garage Door	52	Washer B (Spin)
23	Hair Dryer	53	Water Heater
24	Hair Dryer (Low)	54	IEC Charger
25	Heat Pump (Hi)	55	Honda Charger
26	Heat Pump (Low)	56	Electric Vehicle 3
27	Heat Pump (Medium)	57	Electric Vehicle 4
28	Lap Top	58	Electric Vehicle 5
29	Light Bulb	59	Electric Vehicle 6
30	Mixer A	60	Electric Vehicle 7



Appendix D.1

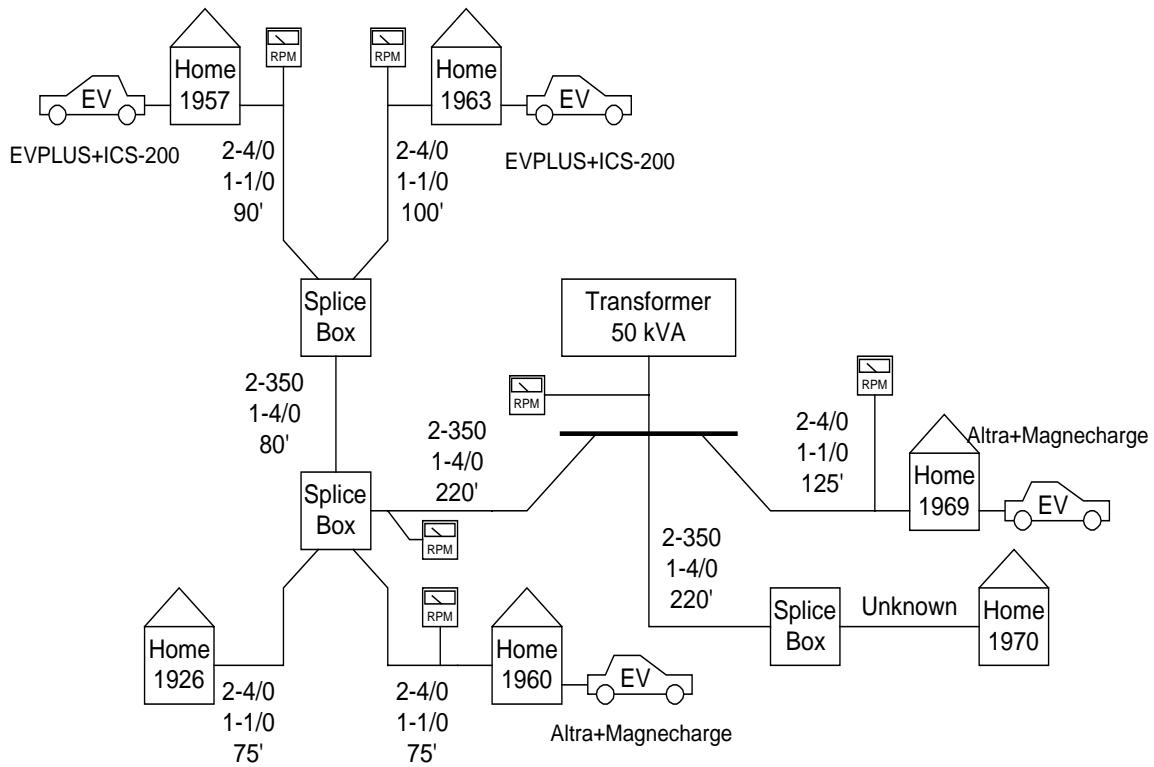
Utility B Data



INDEX

<u>UTILITY B DATA</u>	0
<u>INDEX</u>	1
<u>UTILITY B FIELD SITE LAYOUT</u>	2
<u>UTILITY B DAILY GRAPHS</u>	3
<u>UTILITY B WEEKLY GRAPHS</u>	85

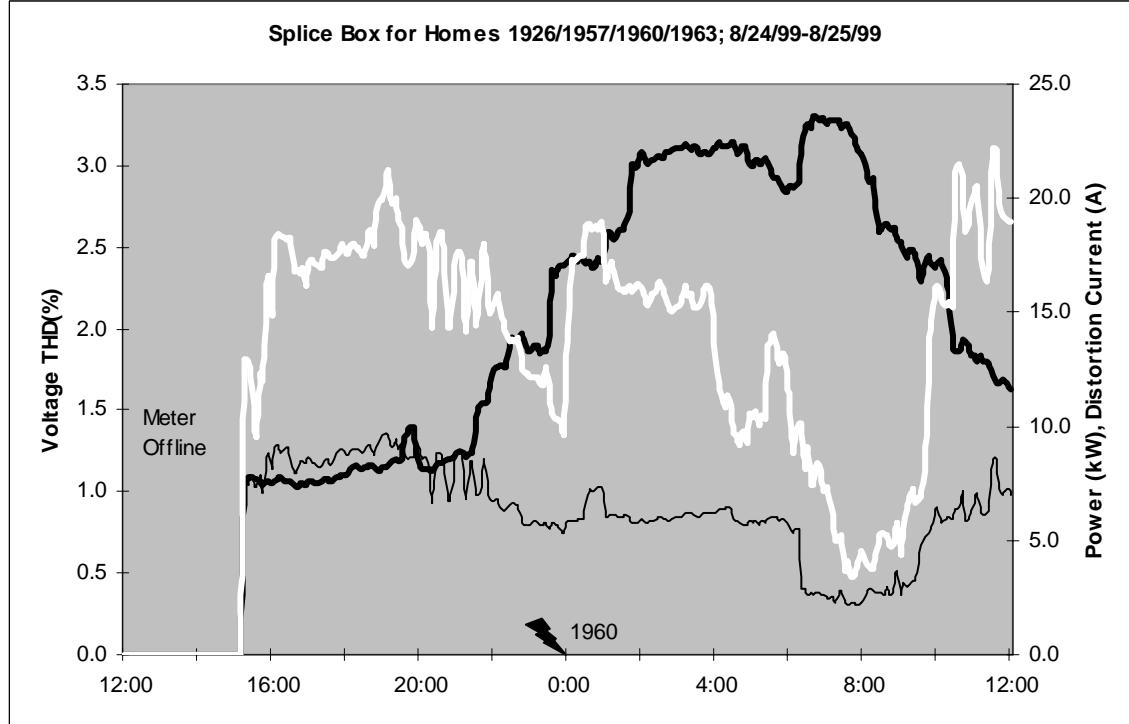
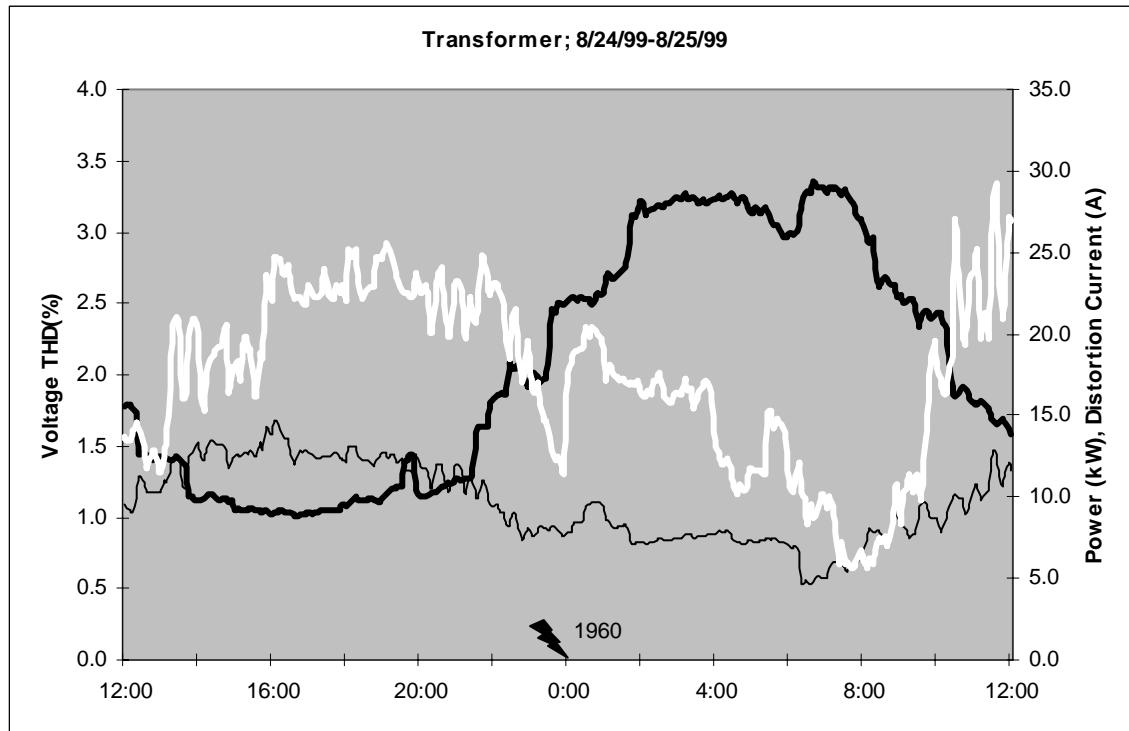
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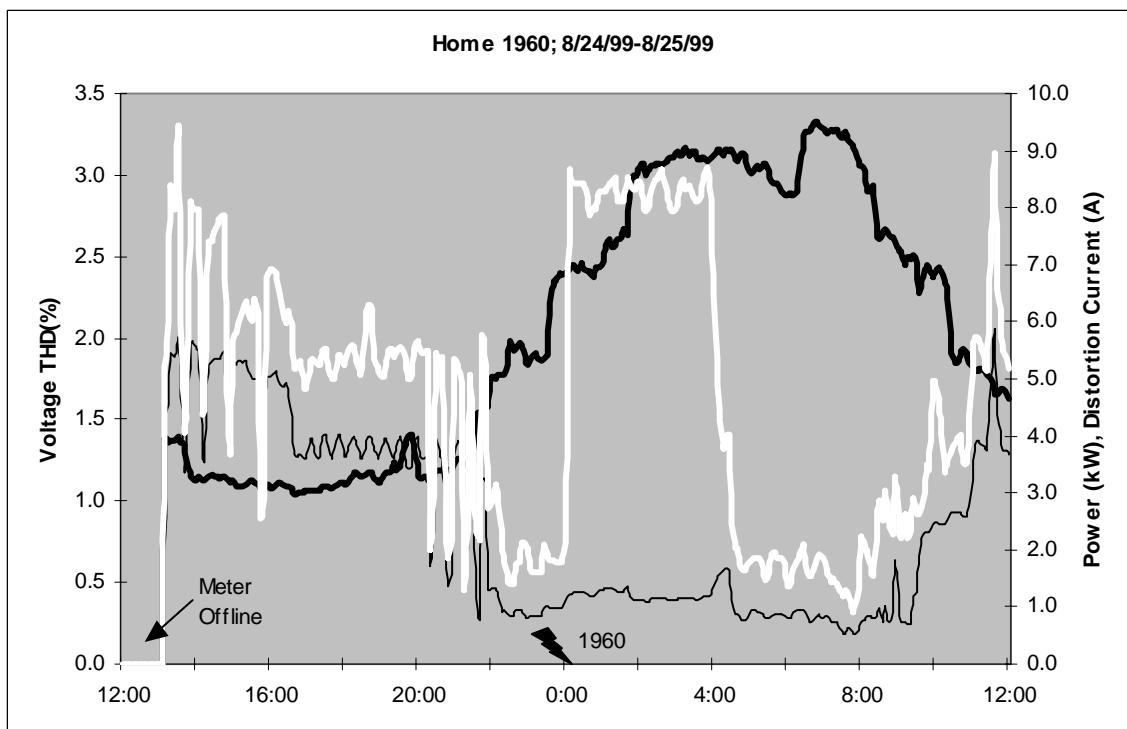
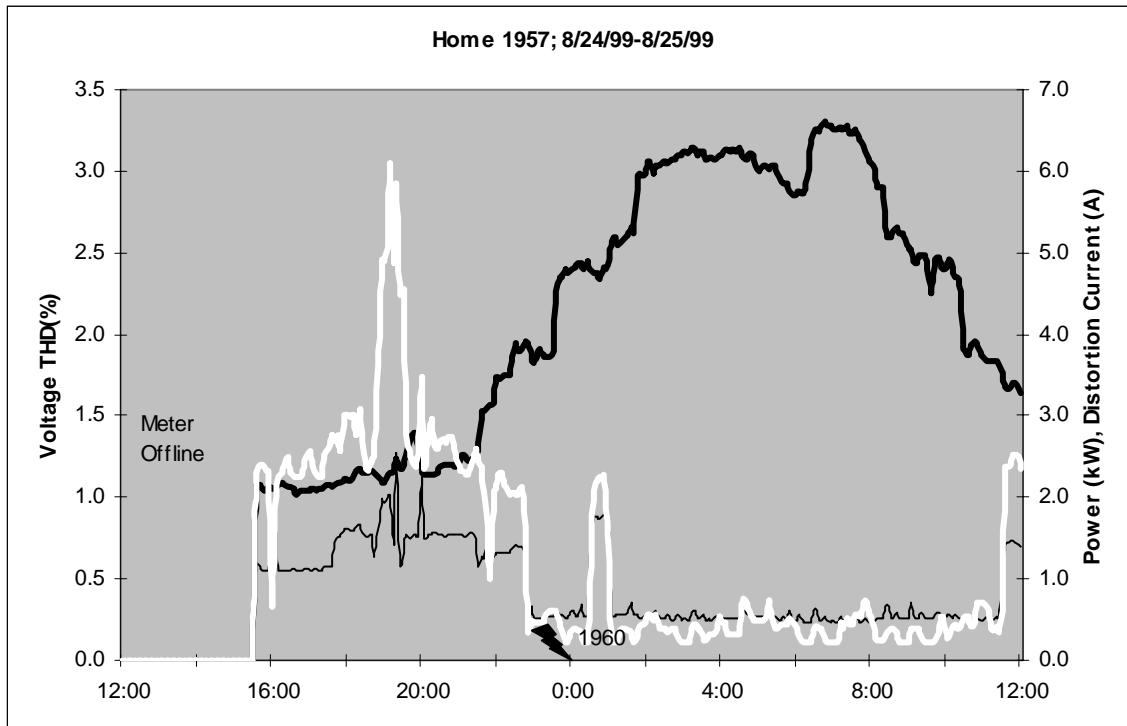


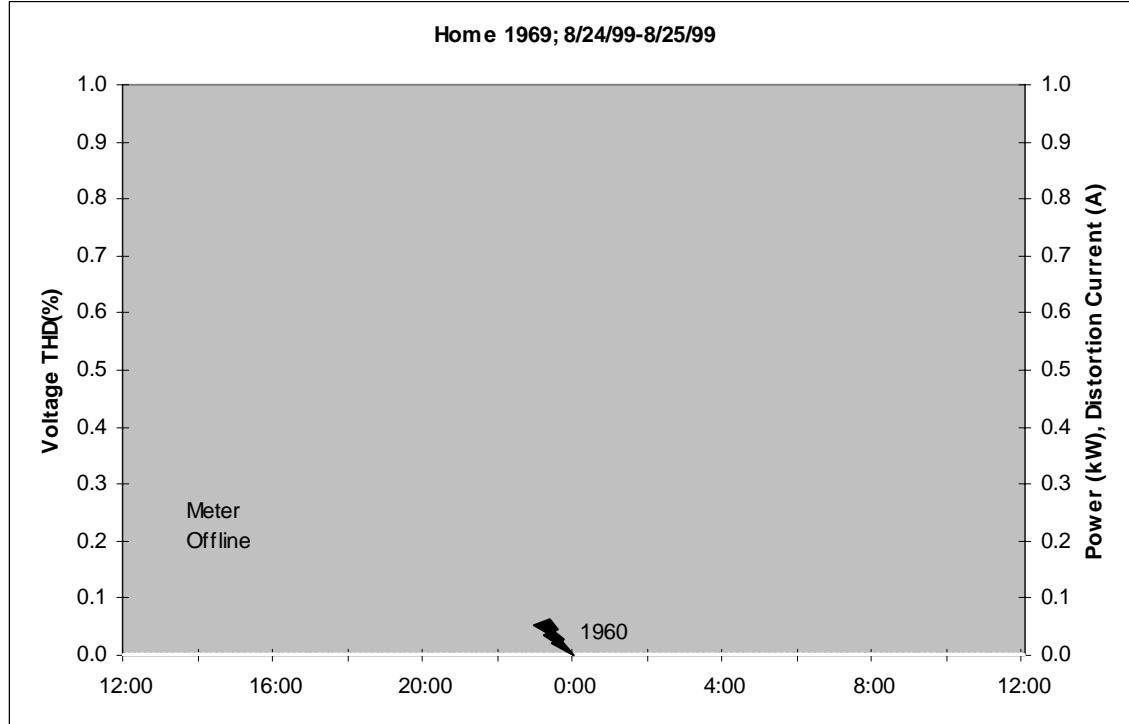
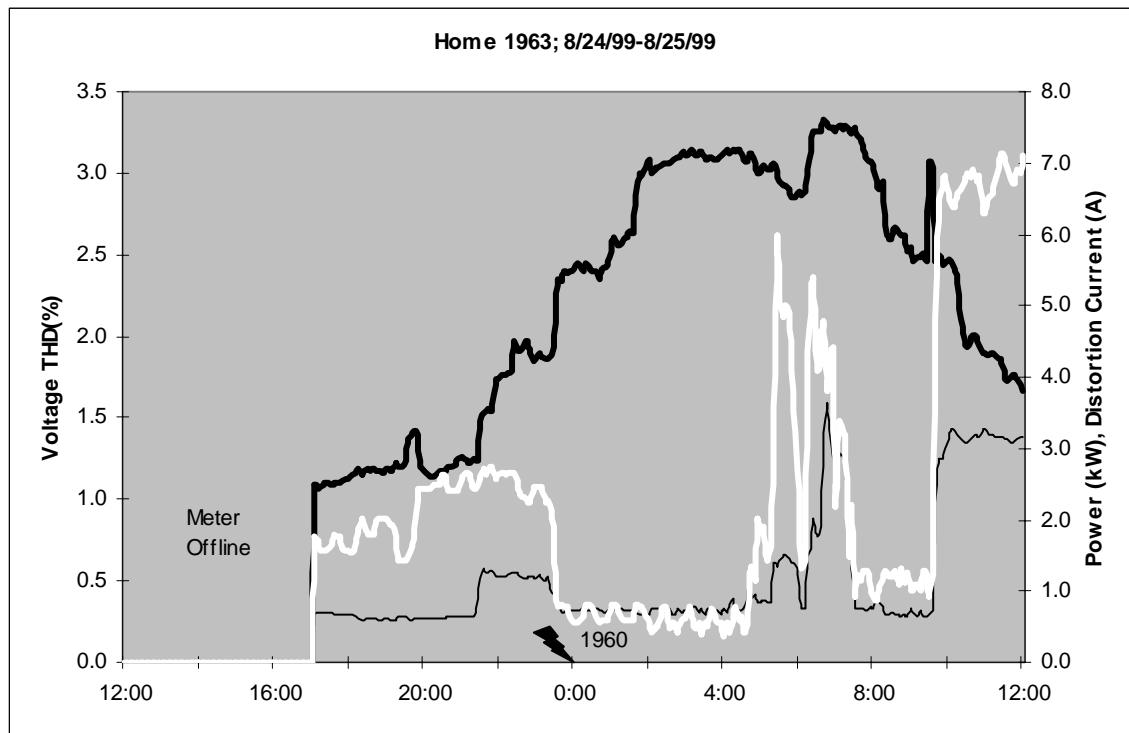
UTILITY B DAILY GRAPHS

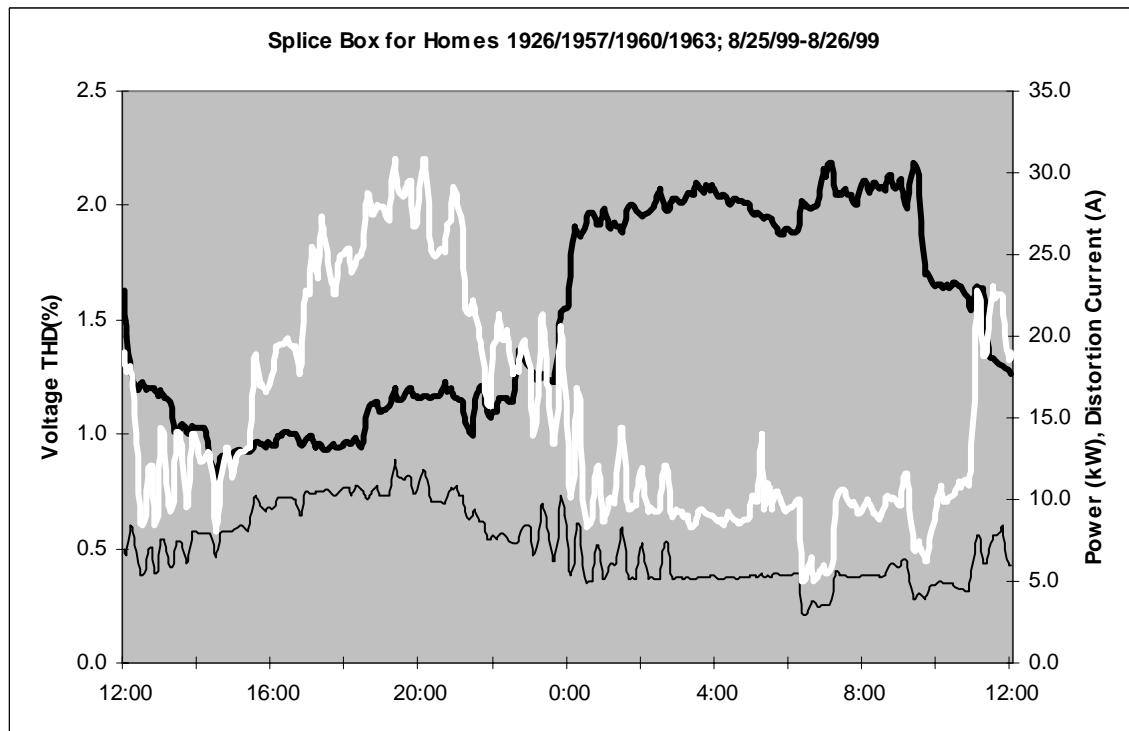
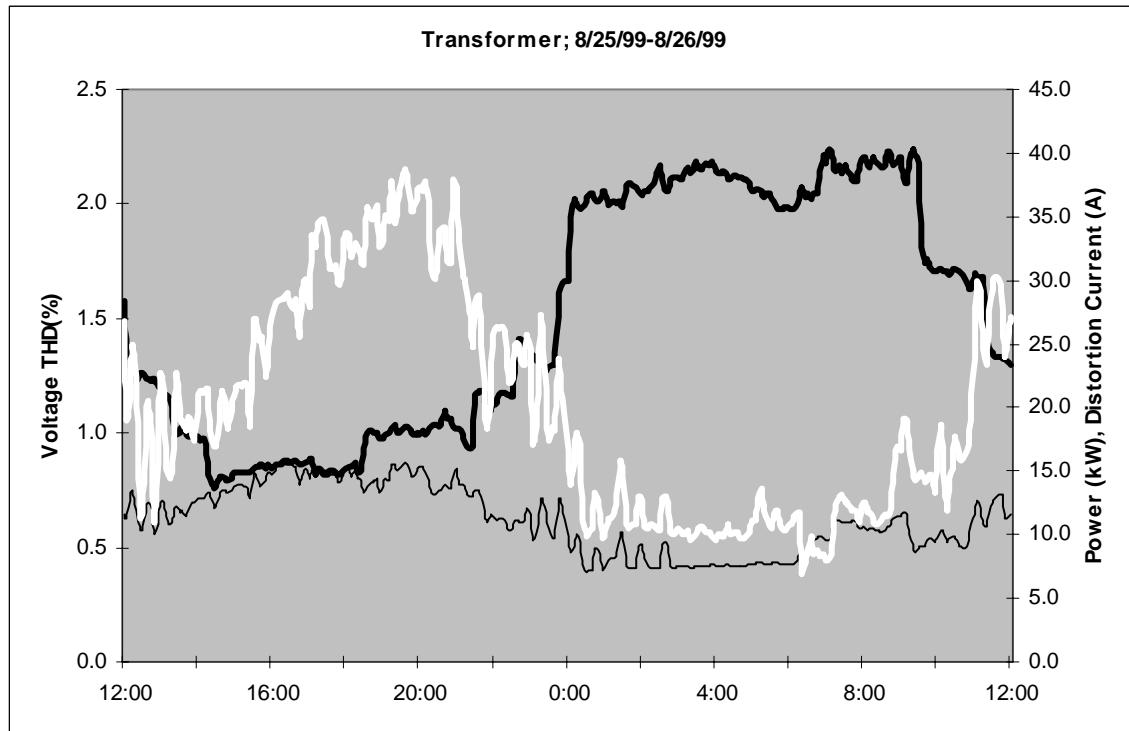


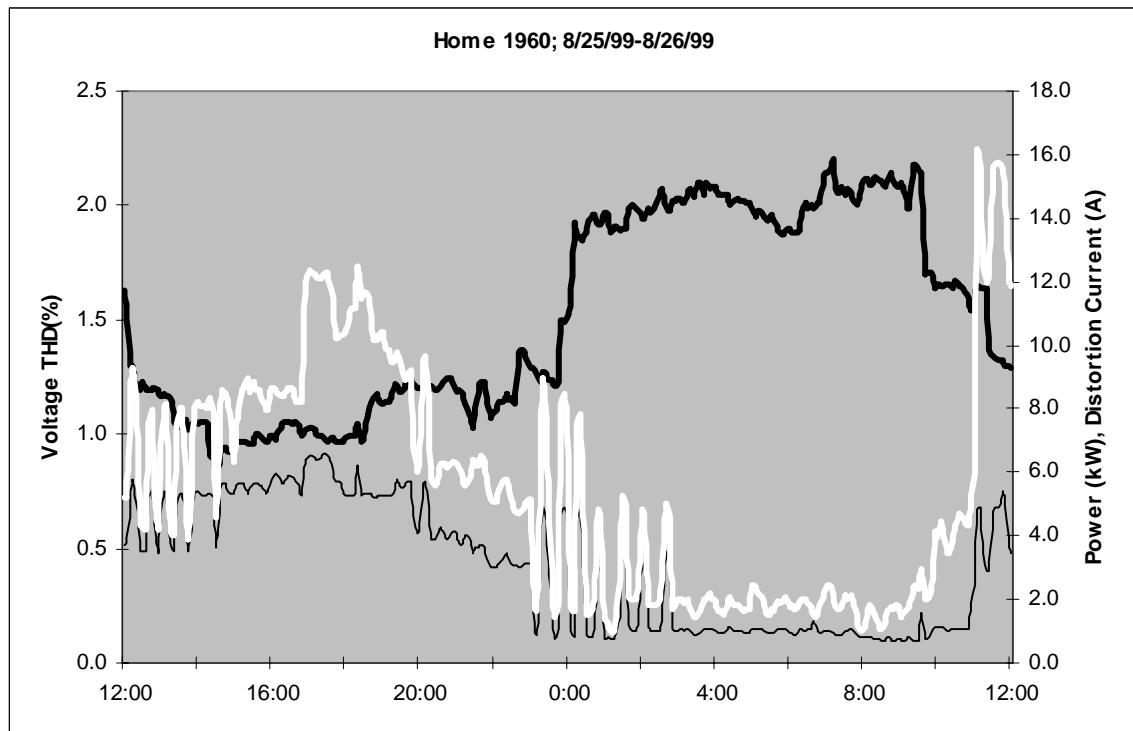
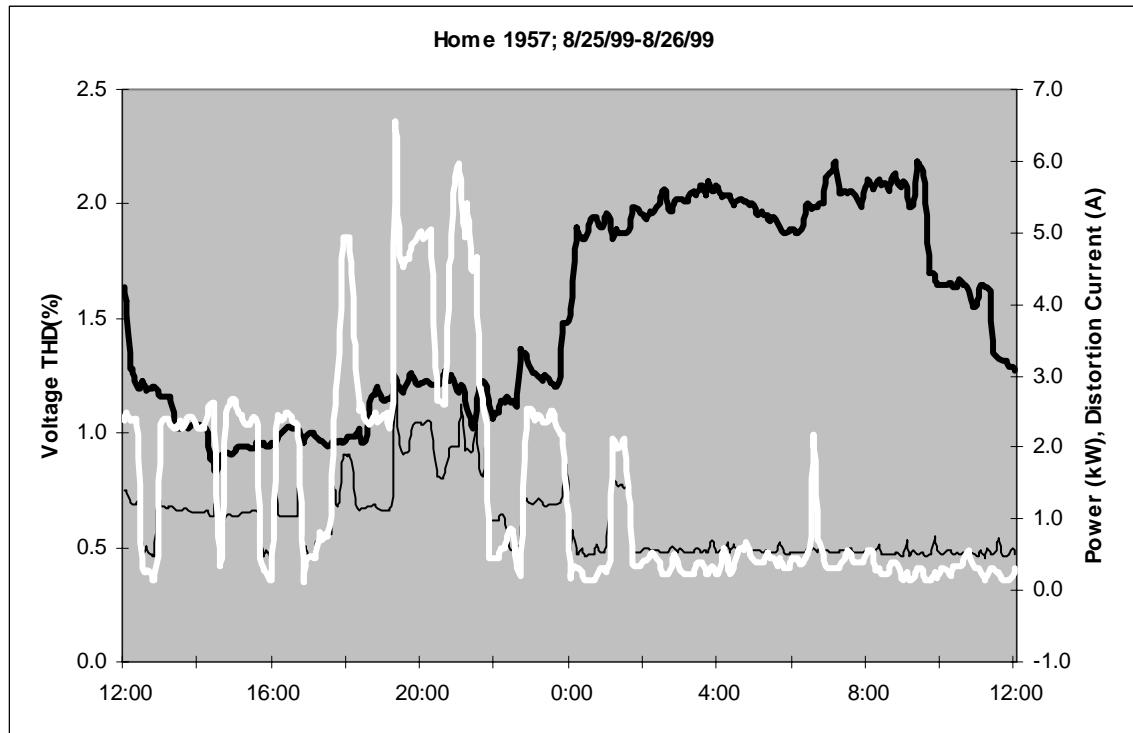
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(Graph Scales are different for clarity)

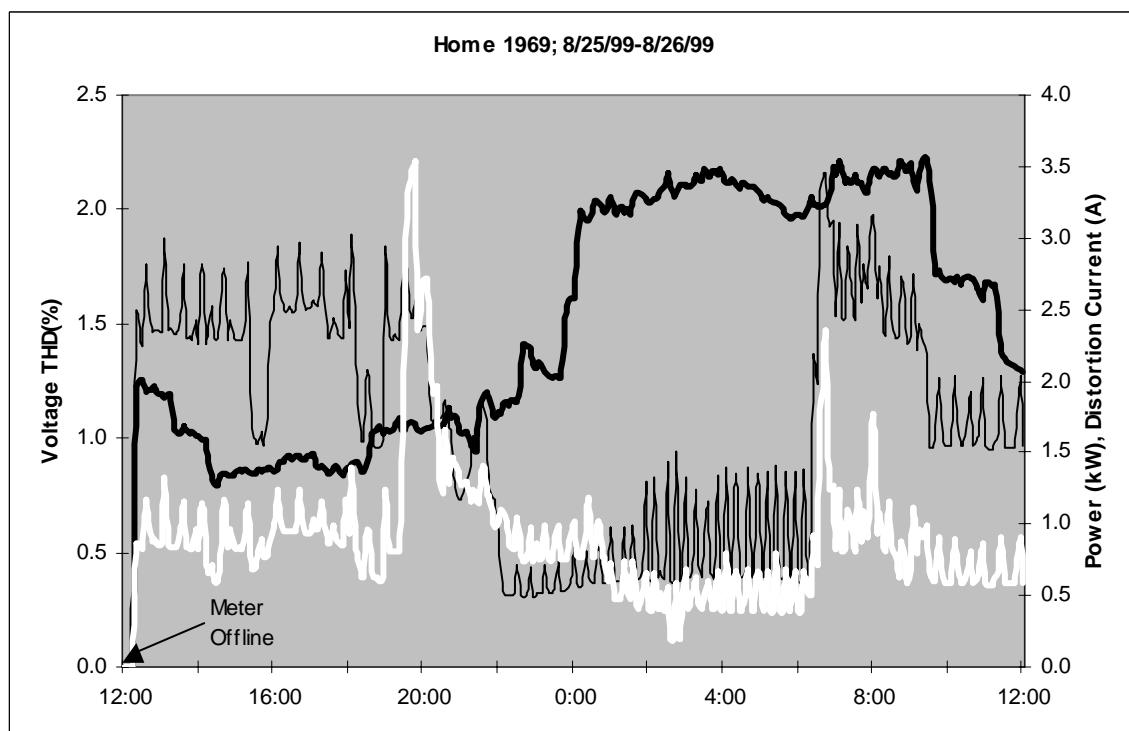
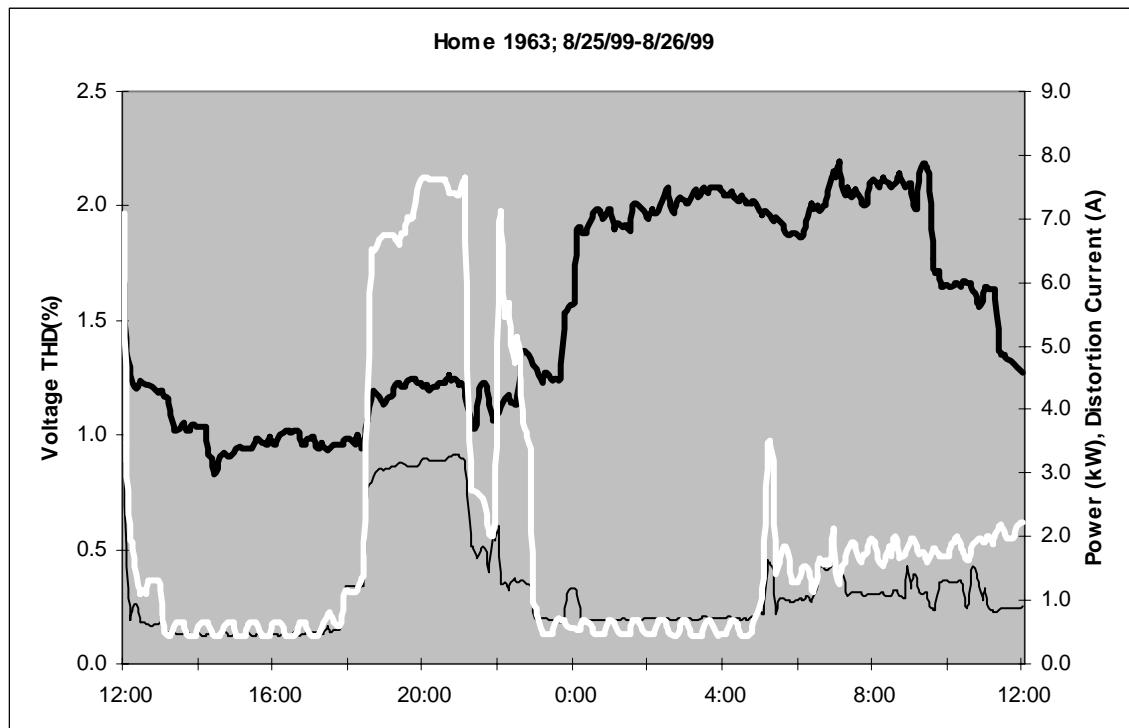


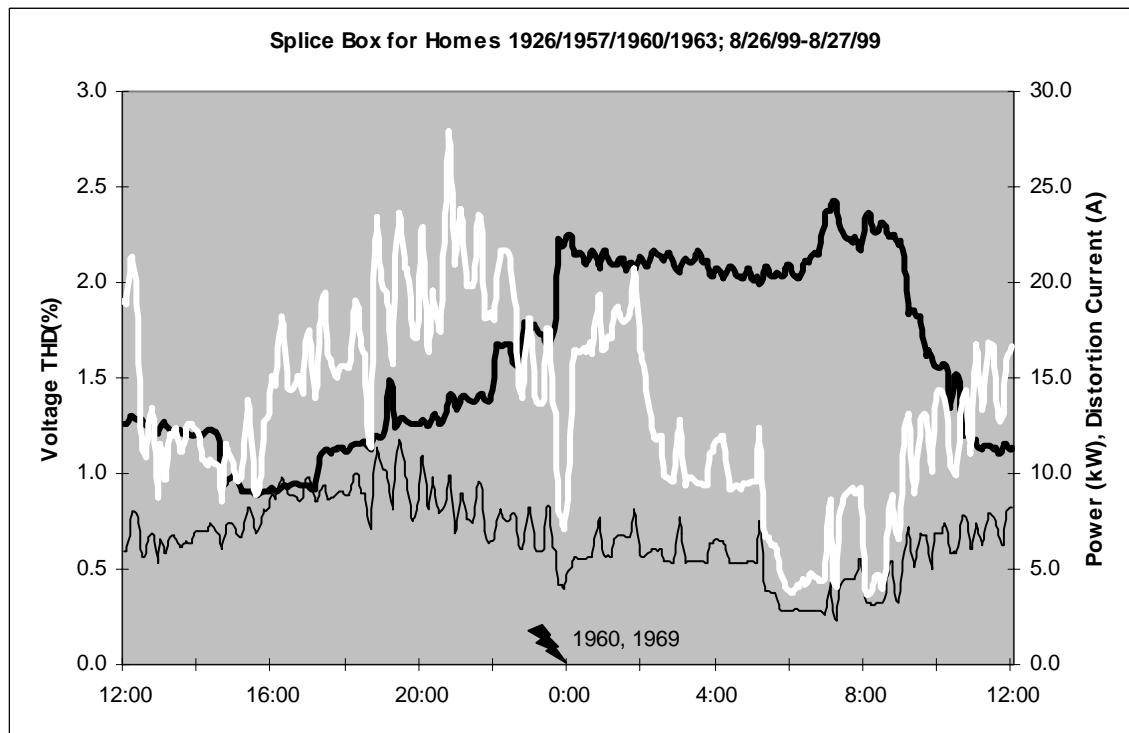
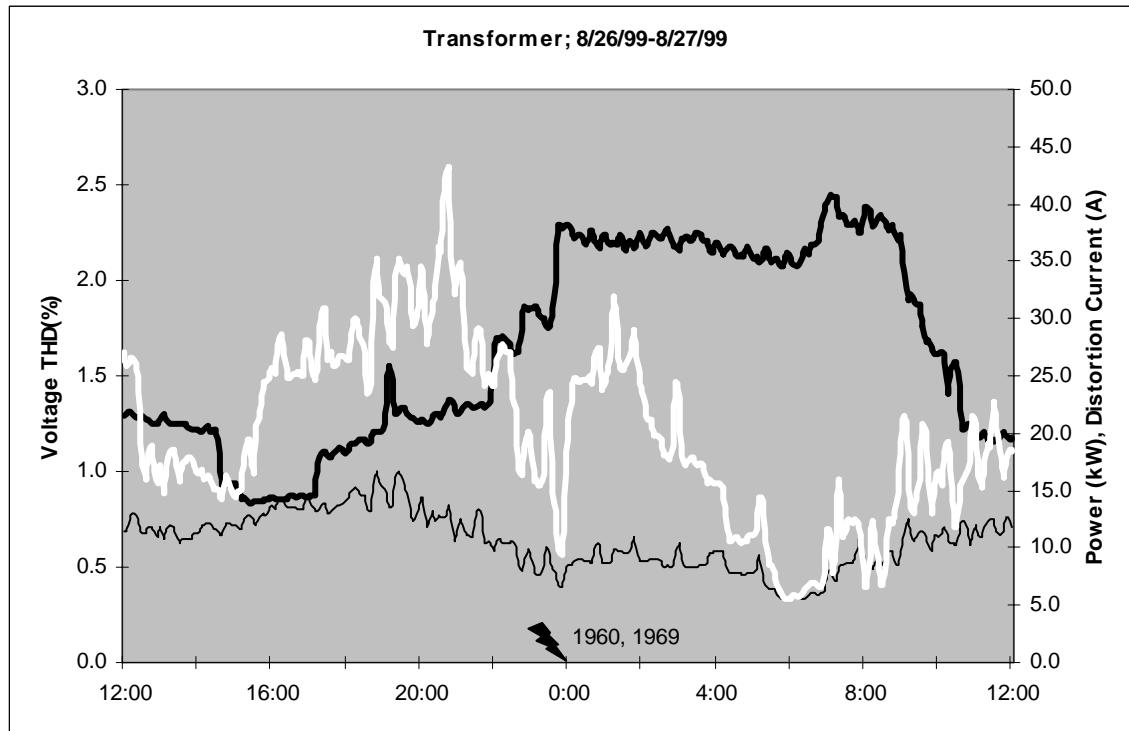


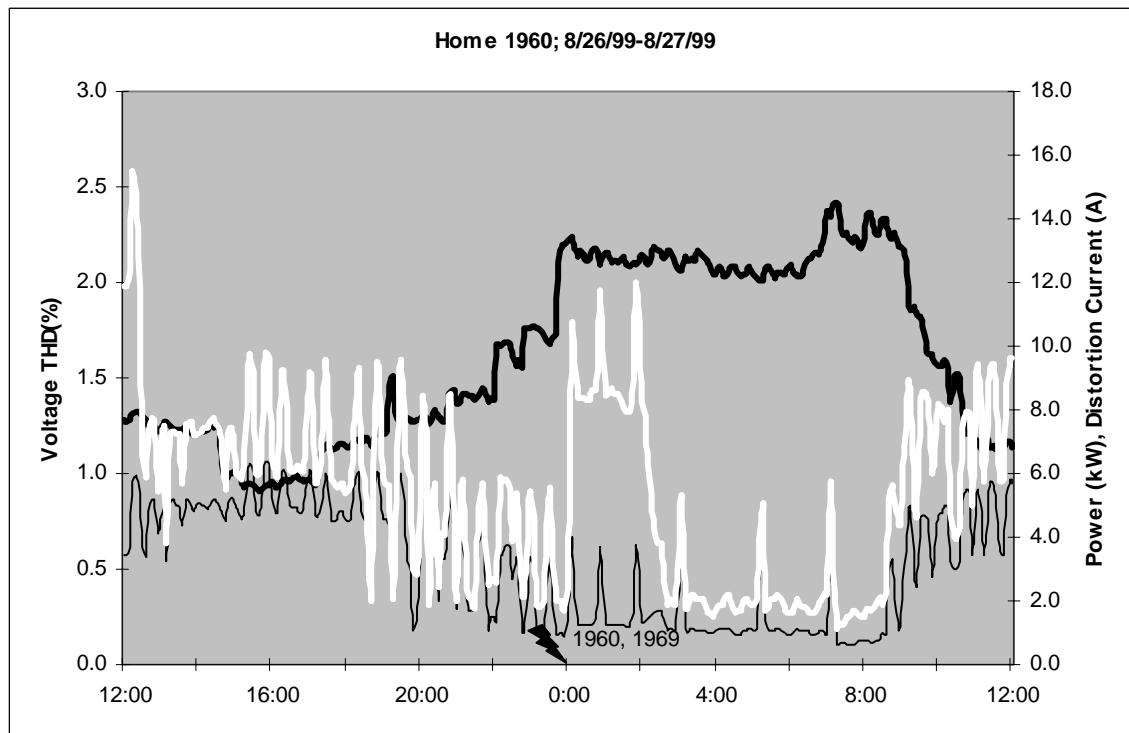
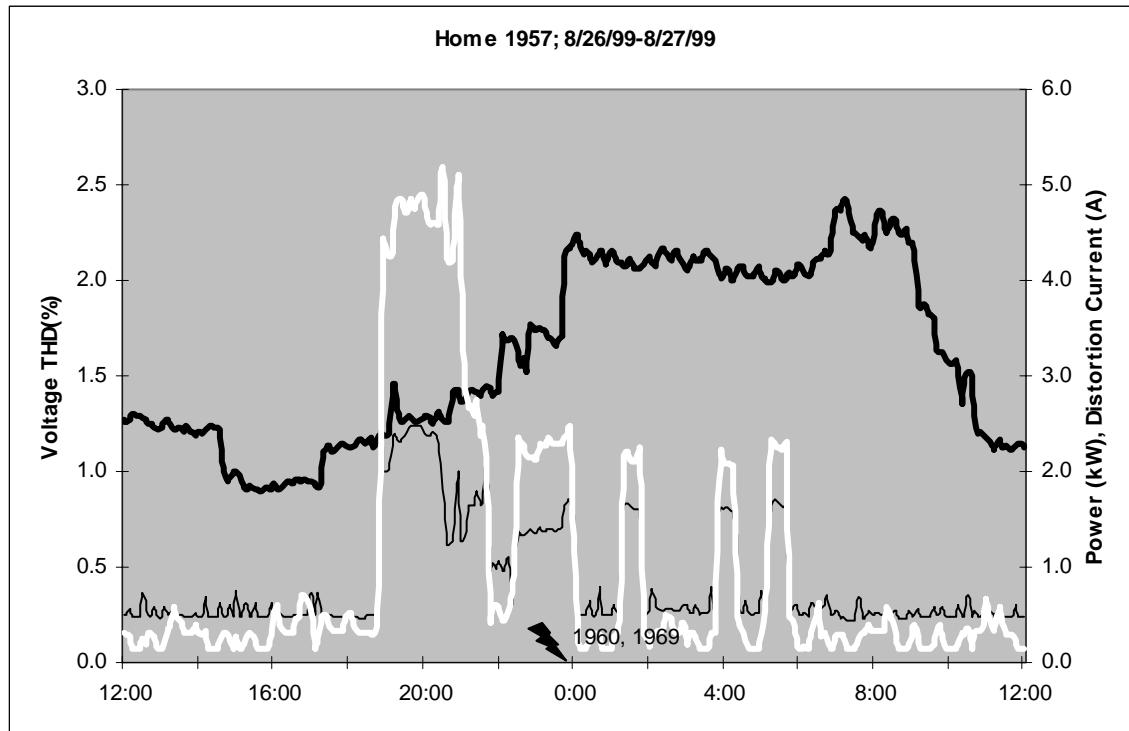


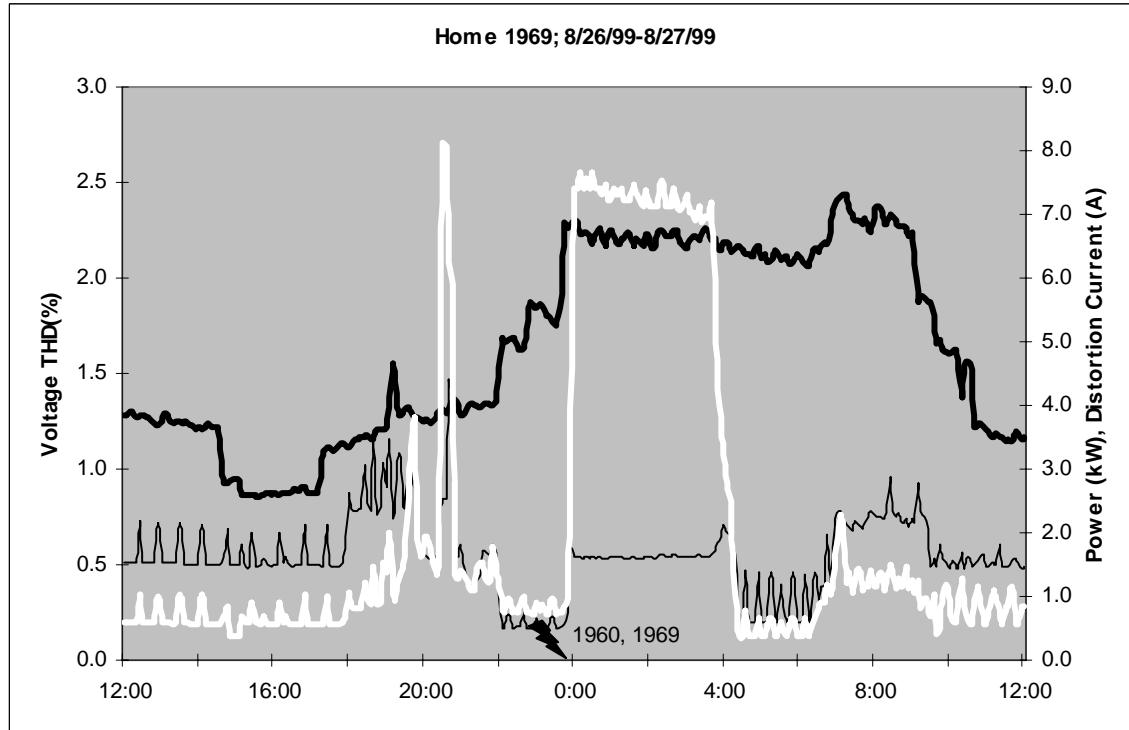
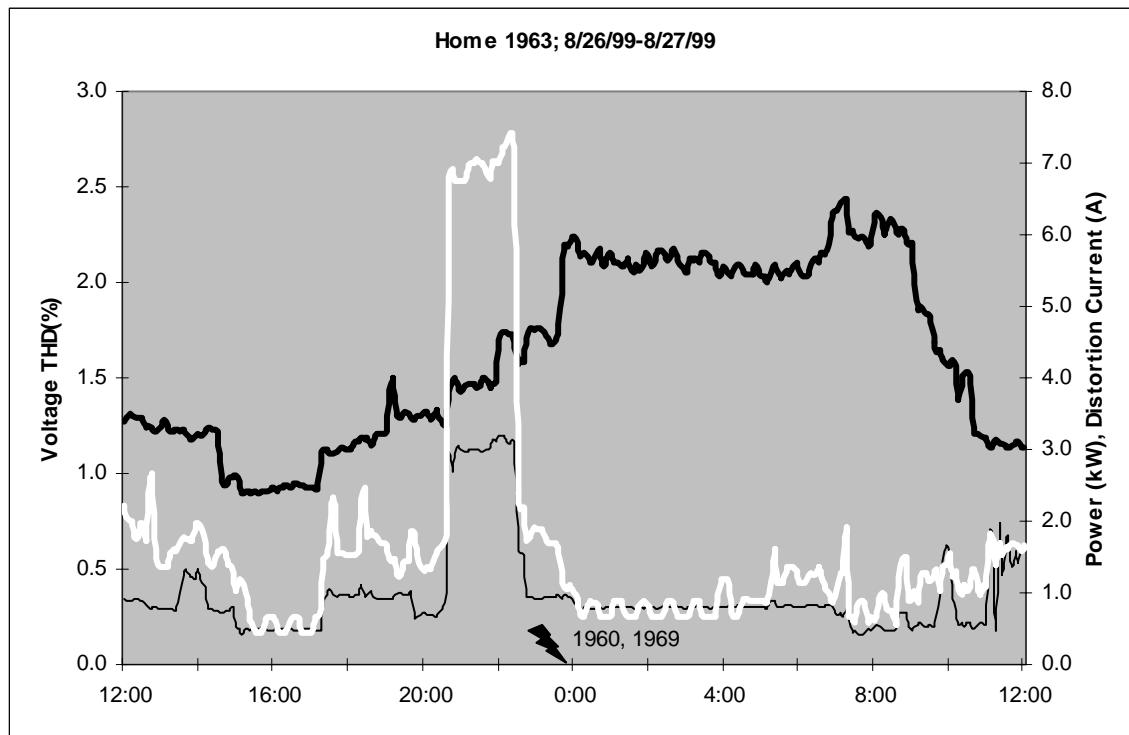


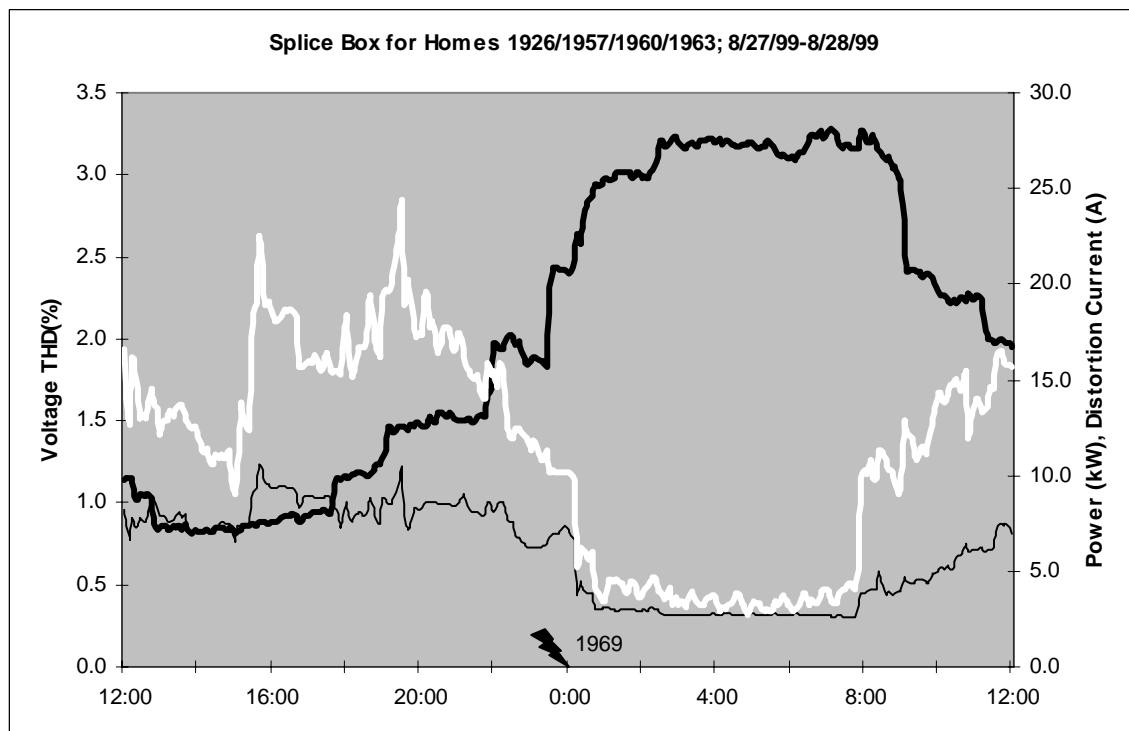
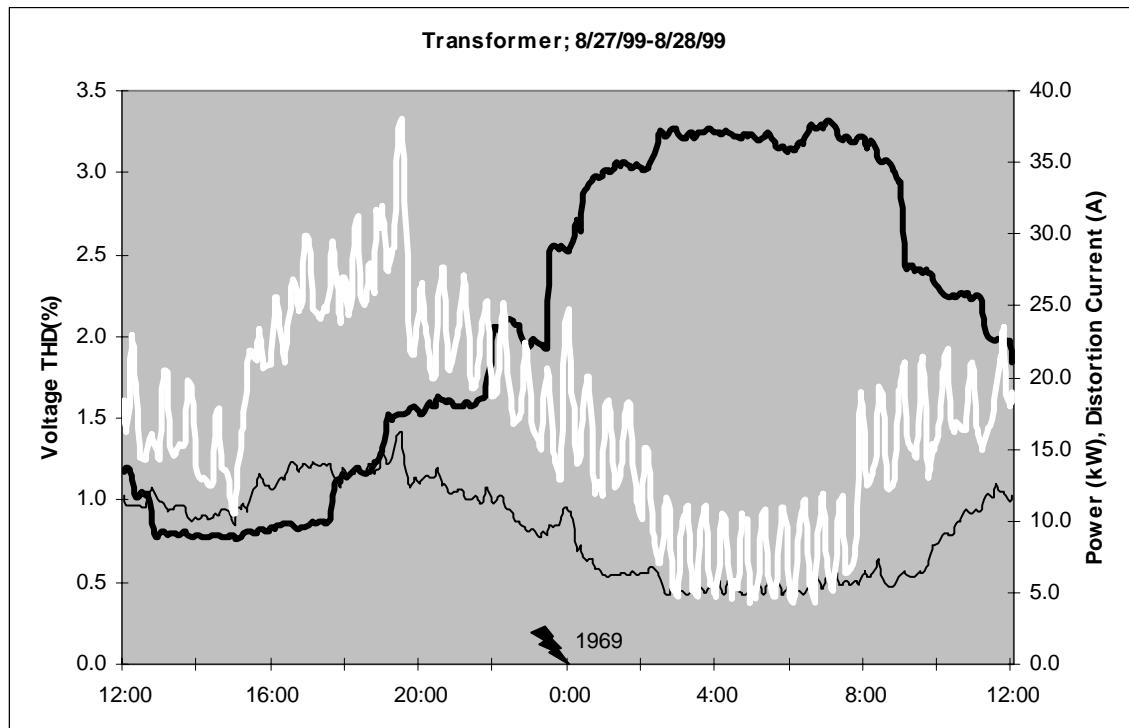


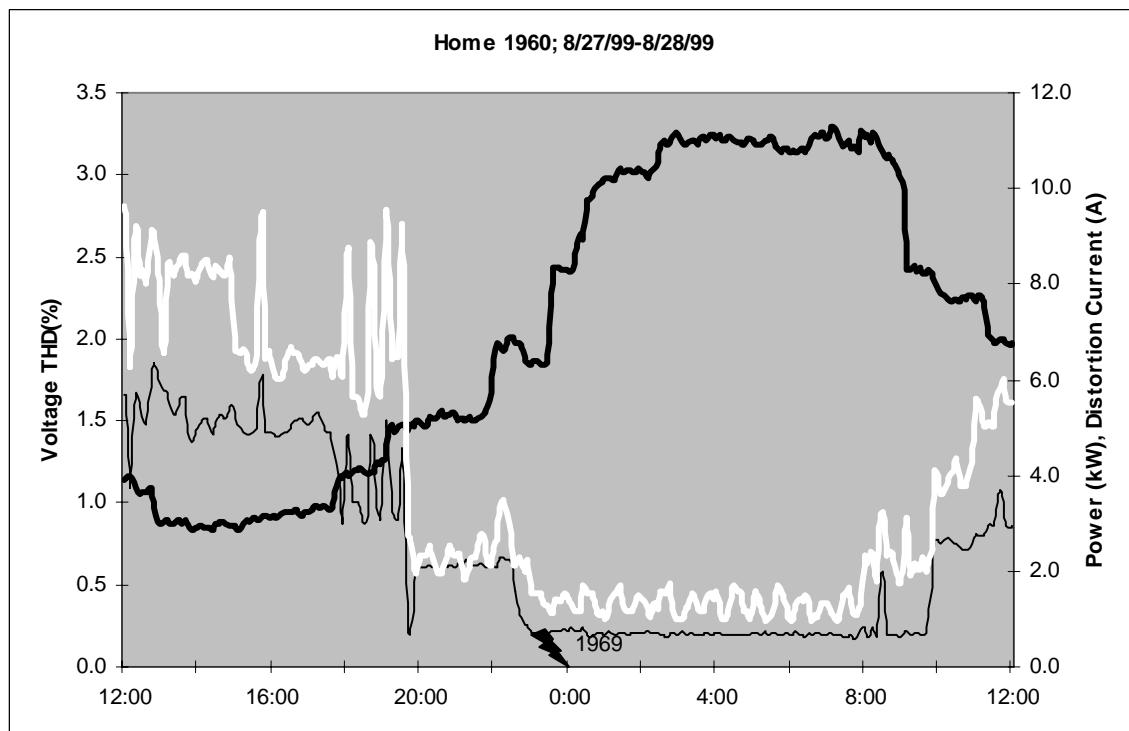
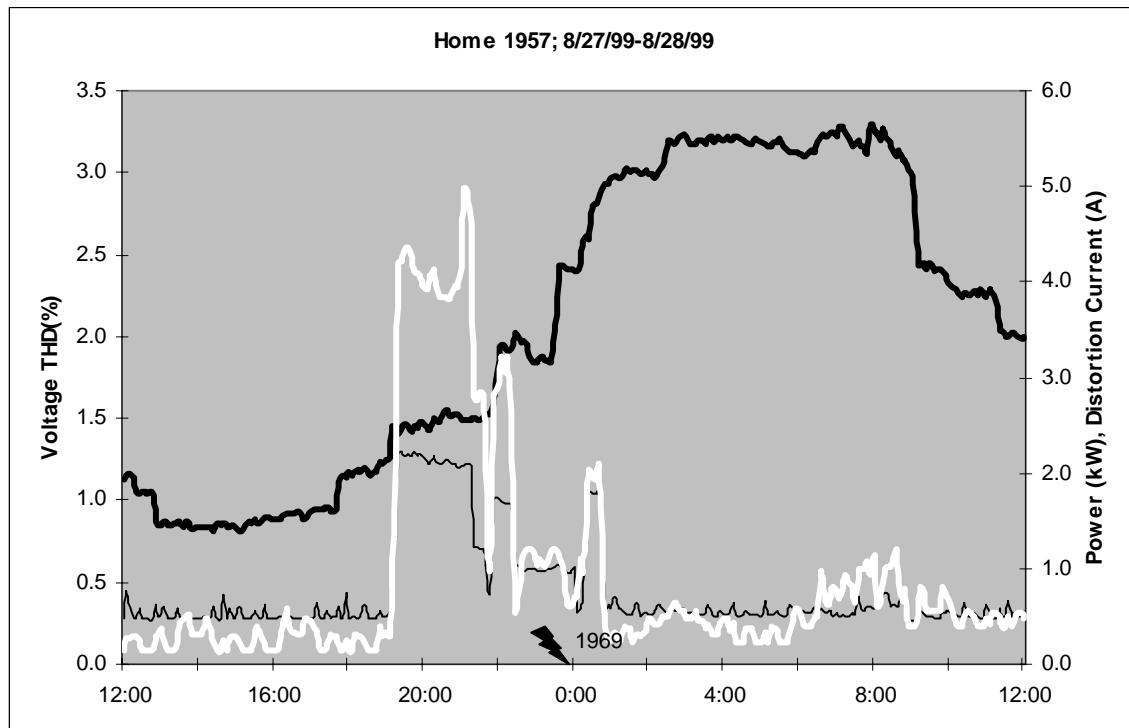


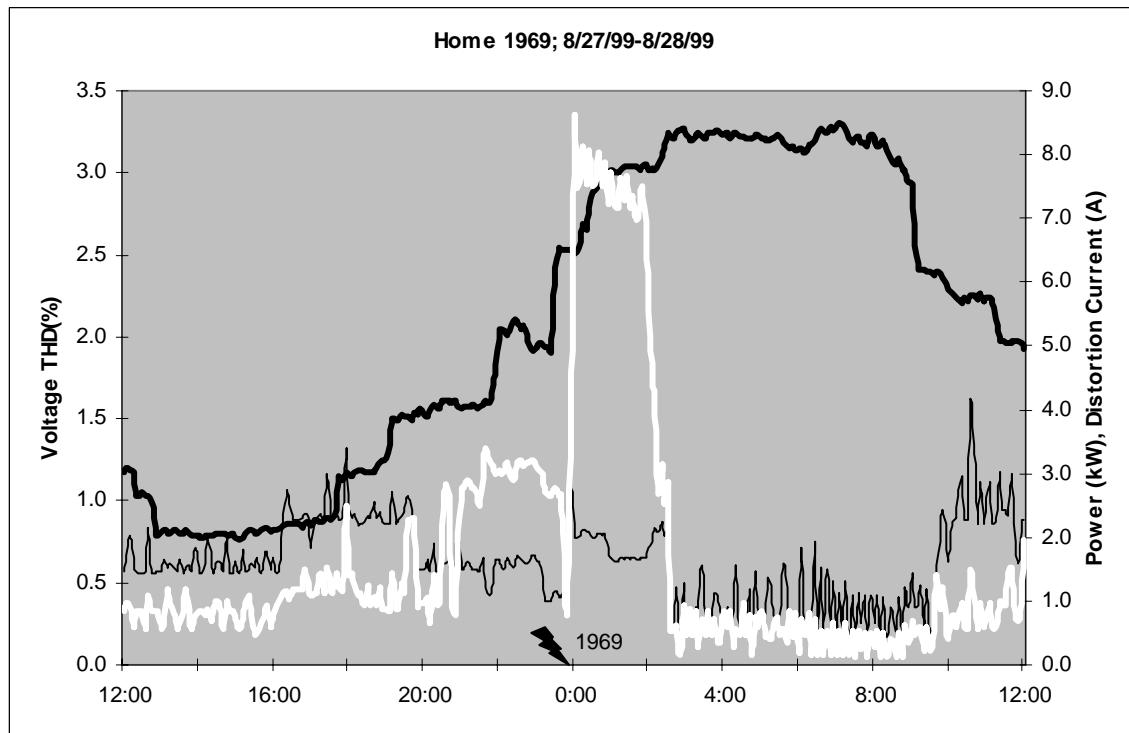
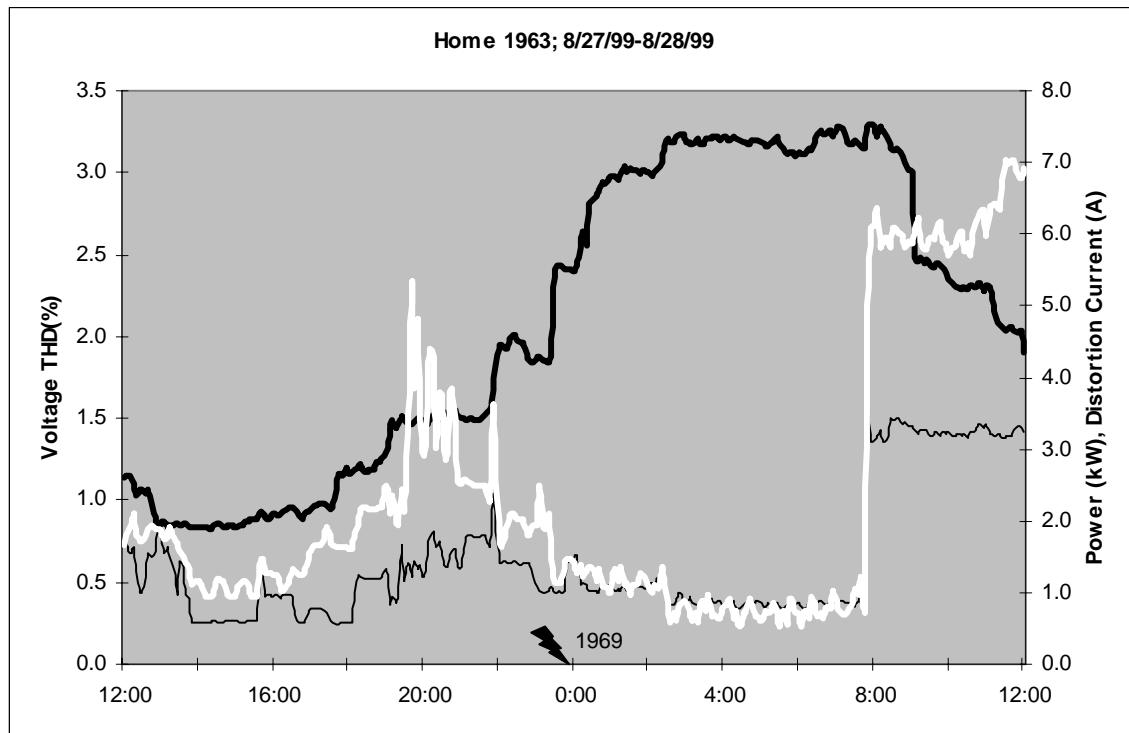


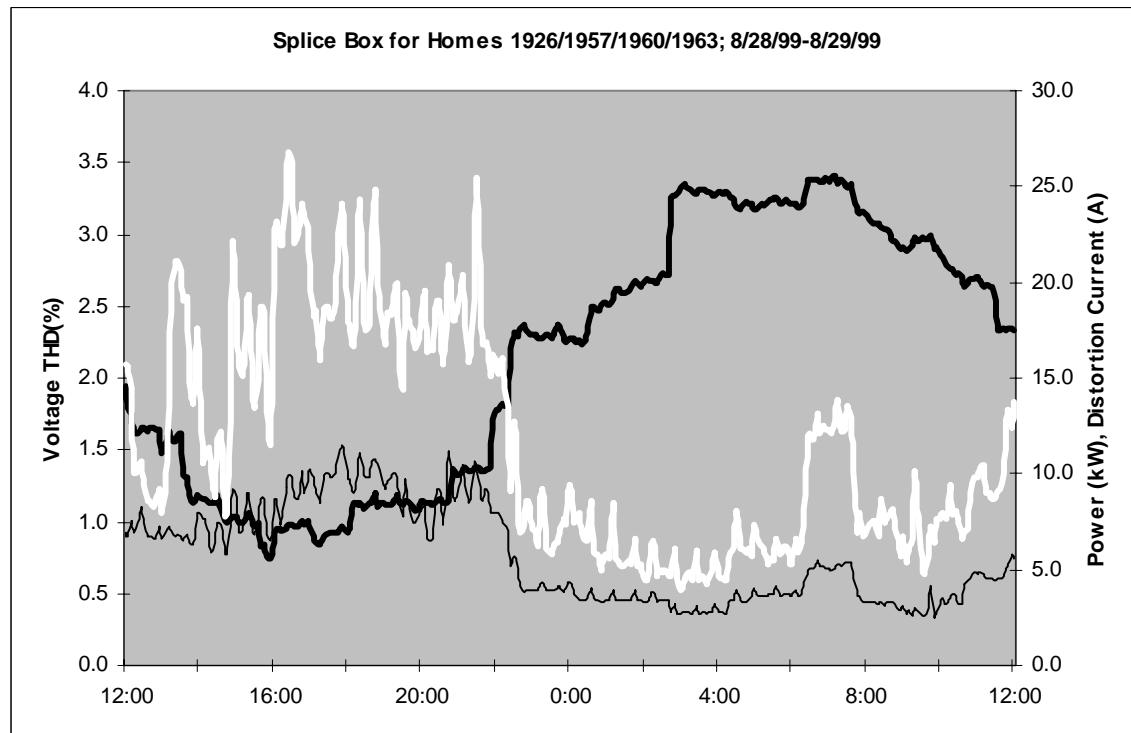
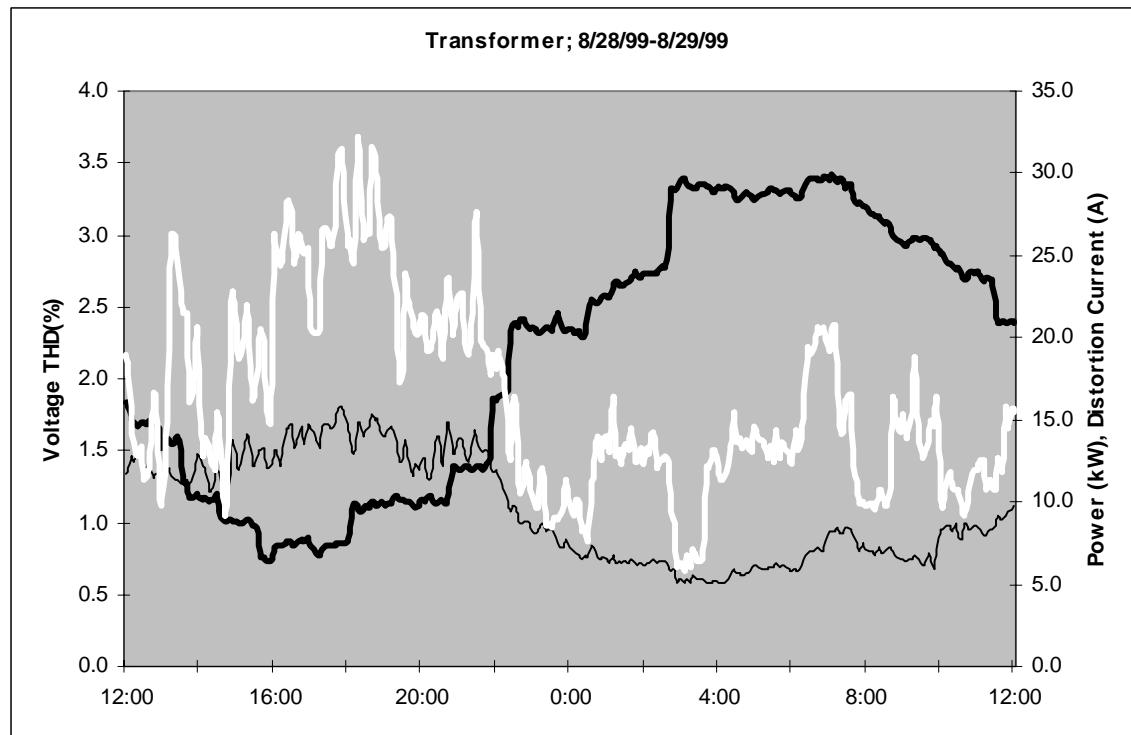


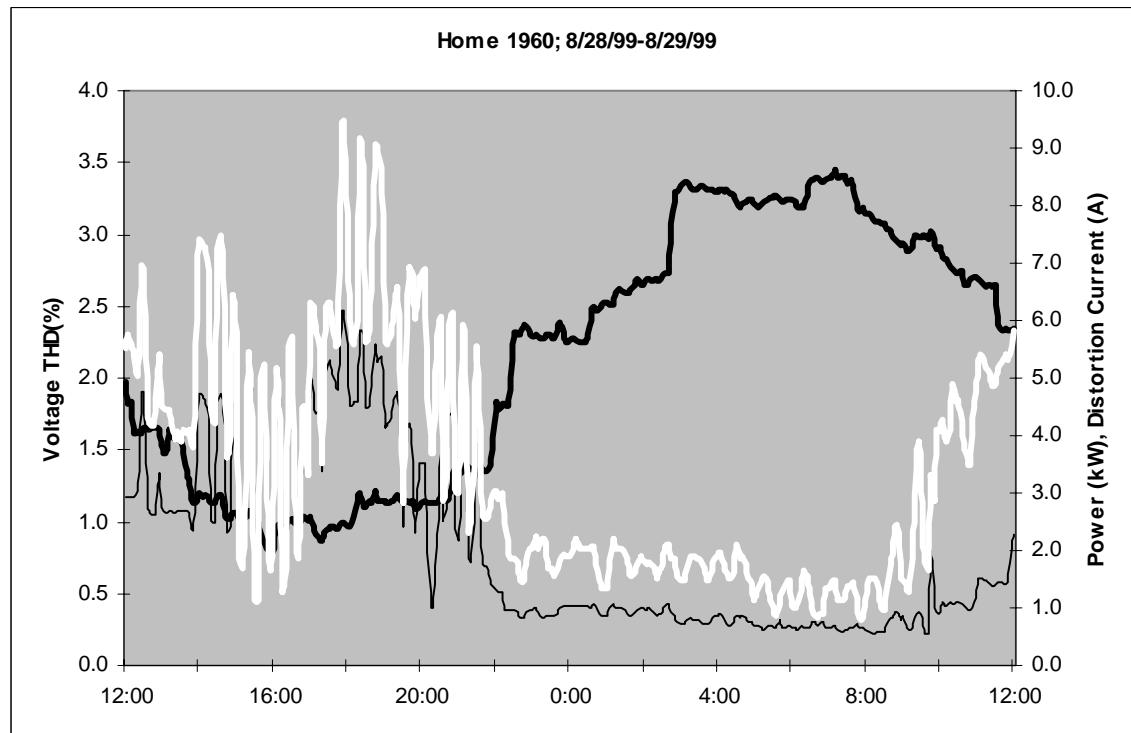
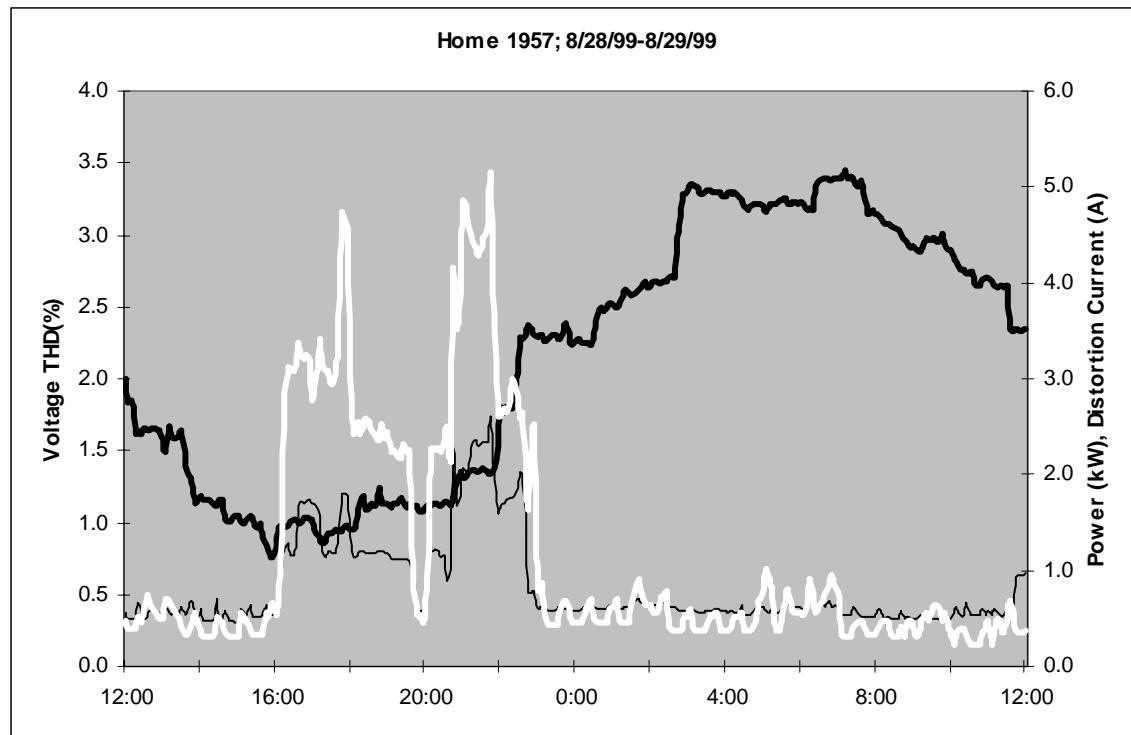


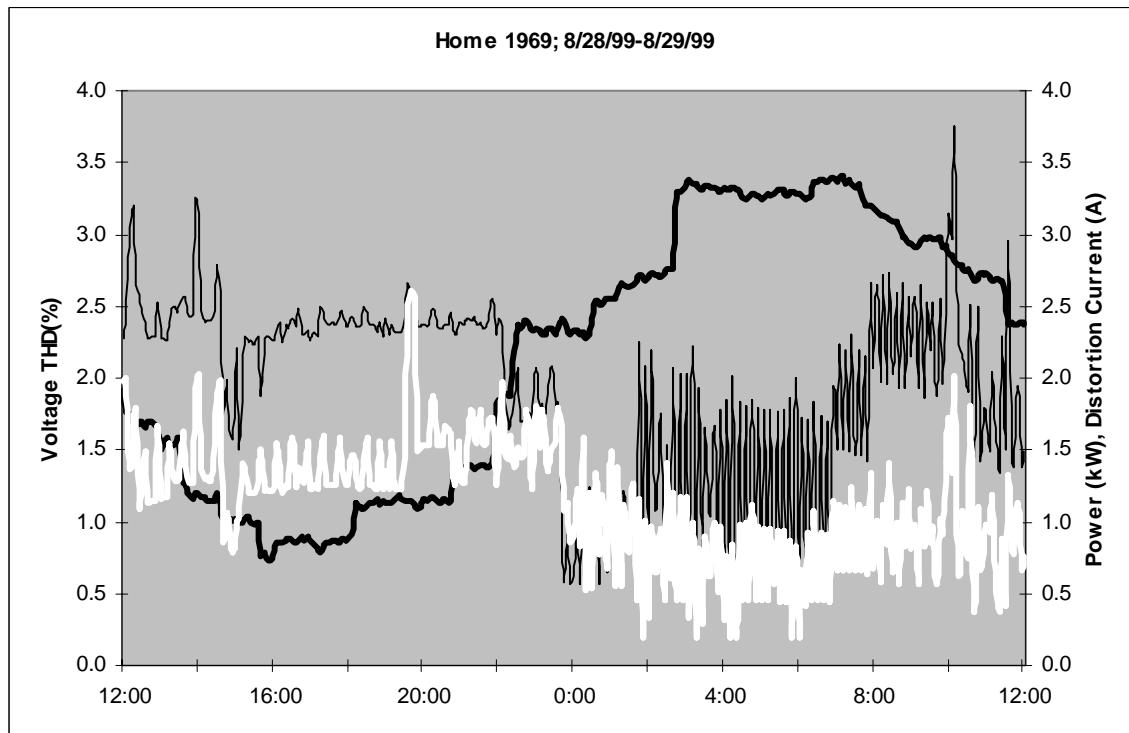
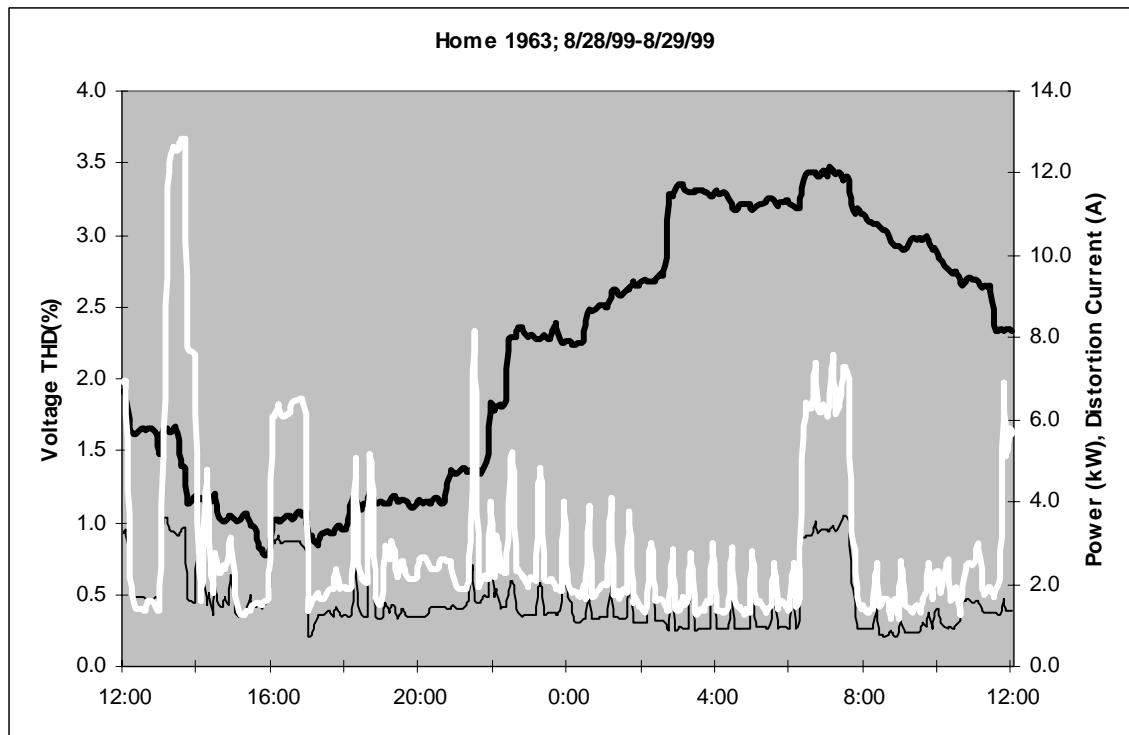


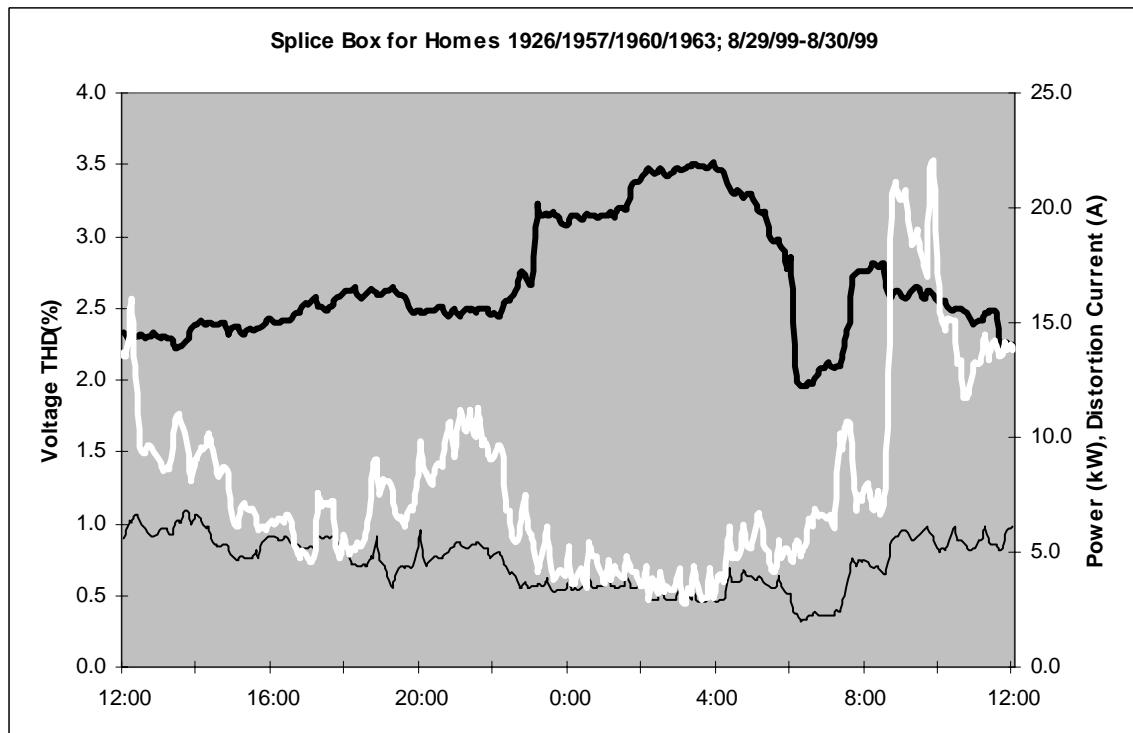
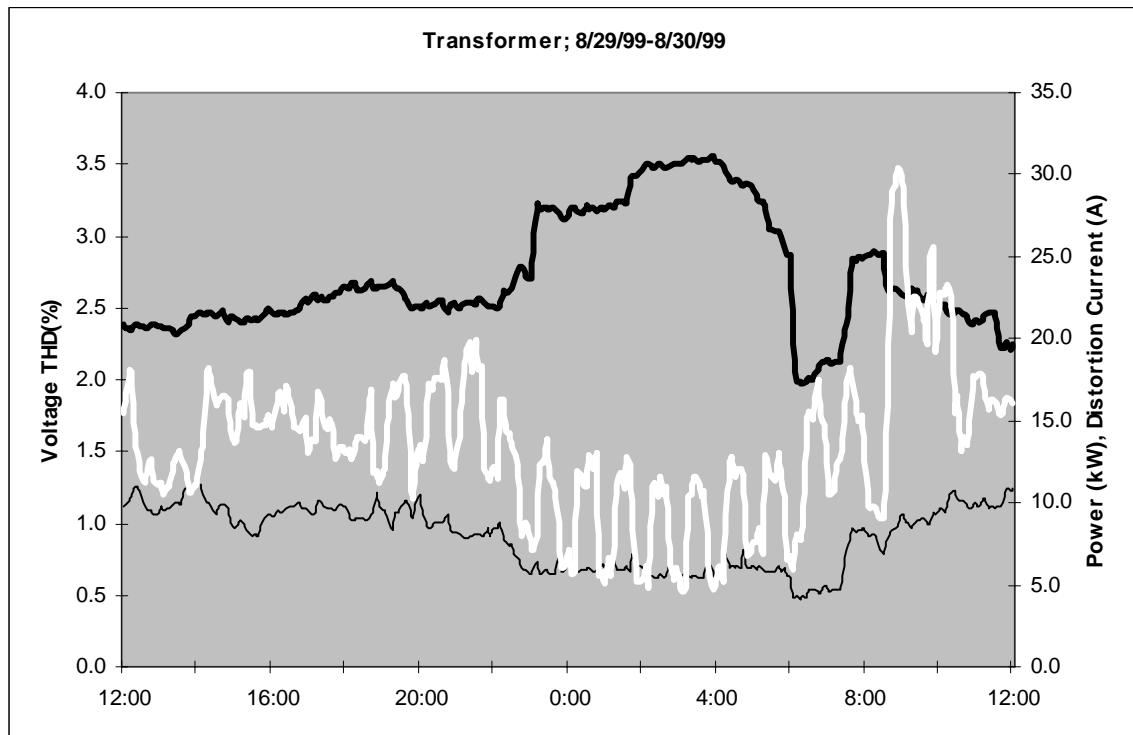


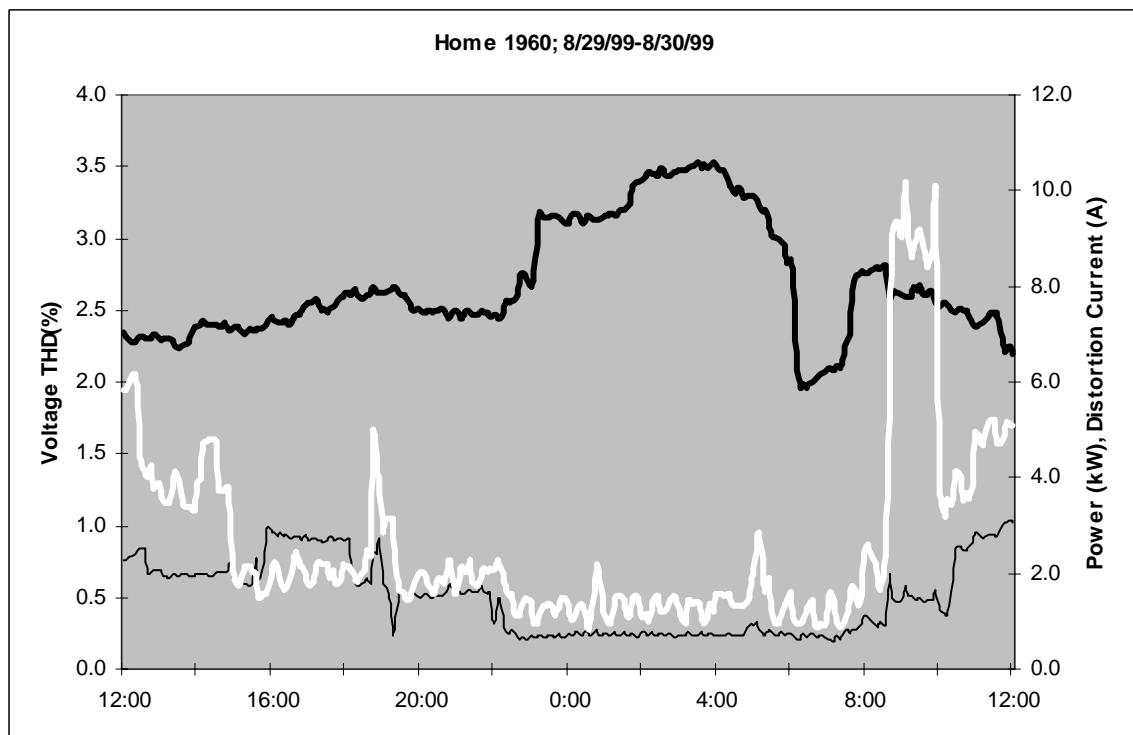
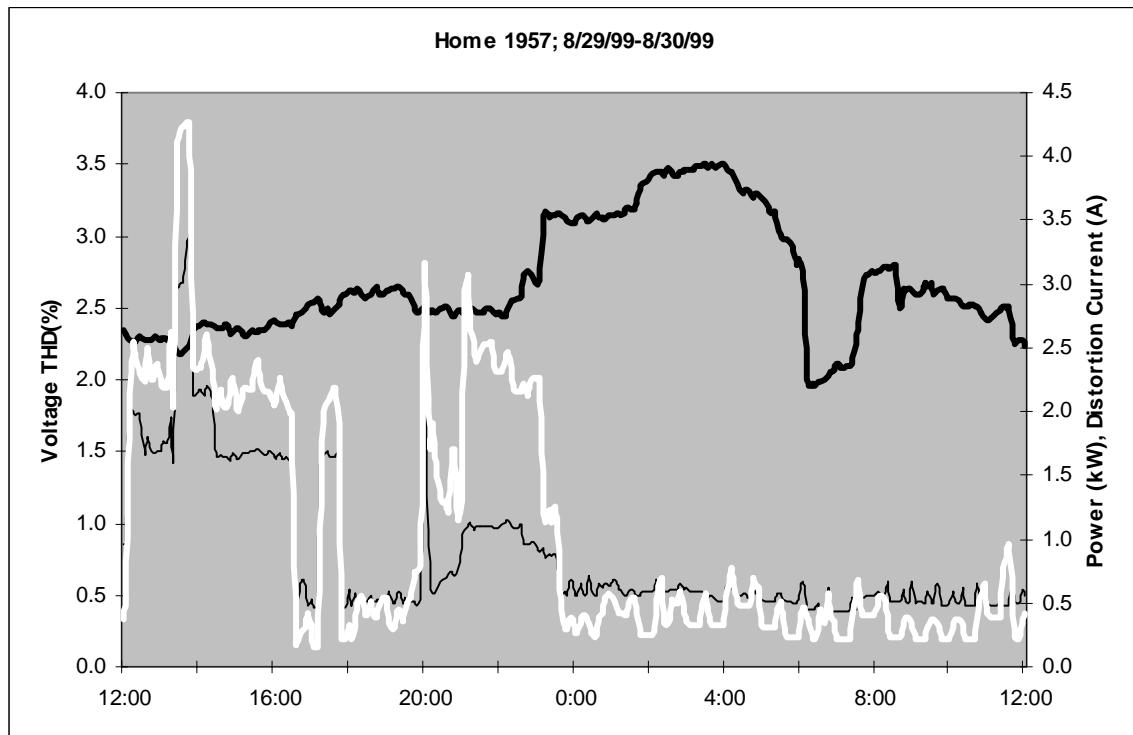


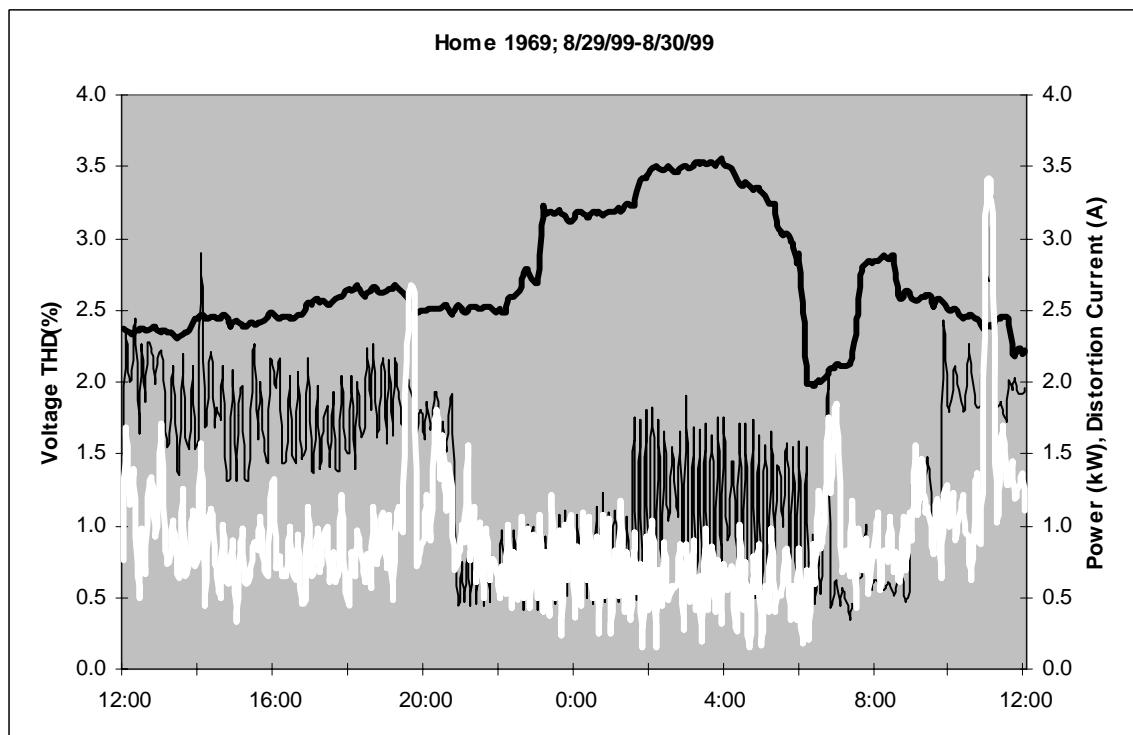
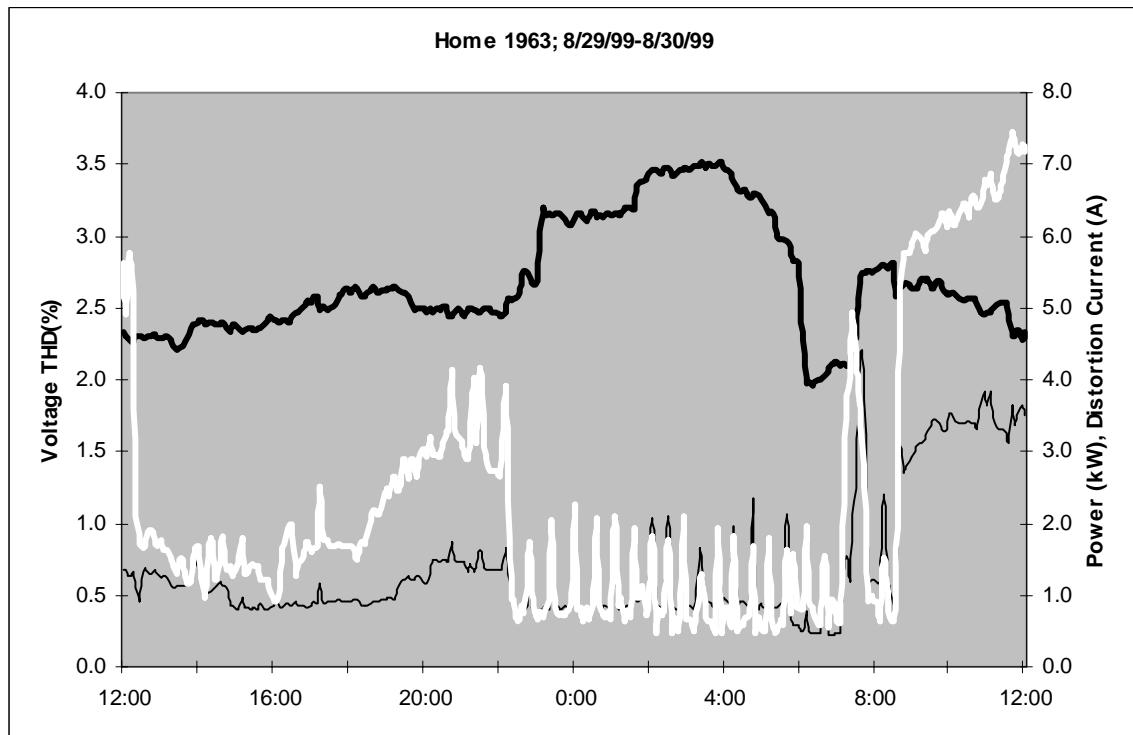


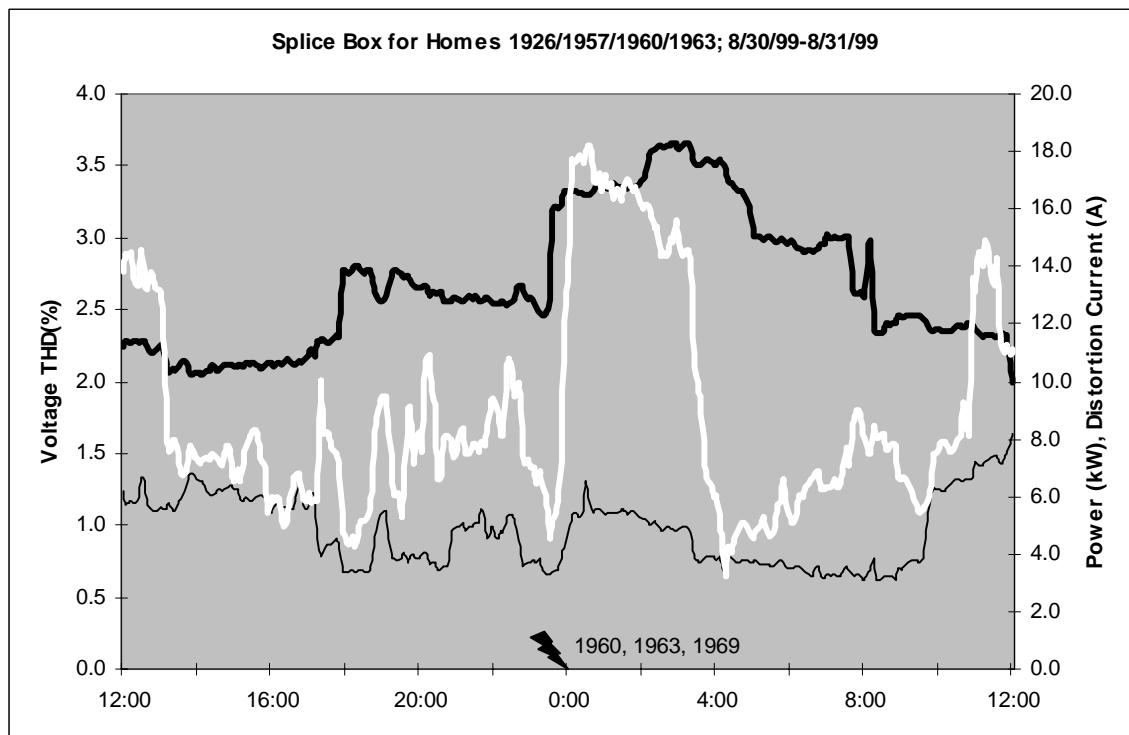
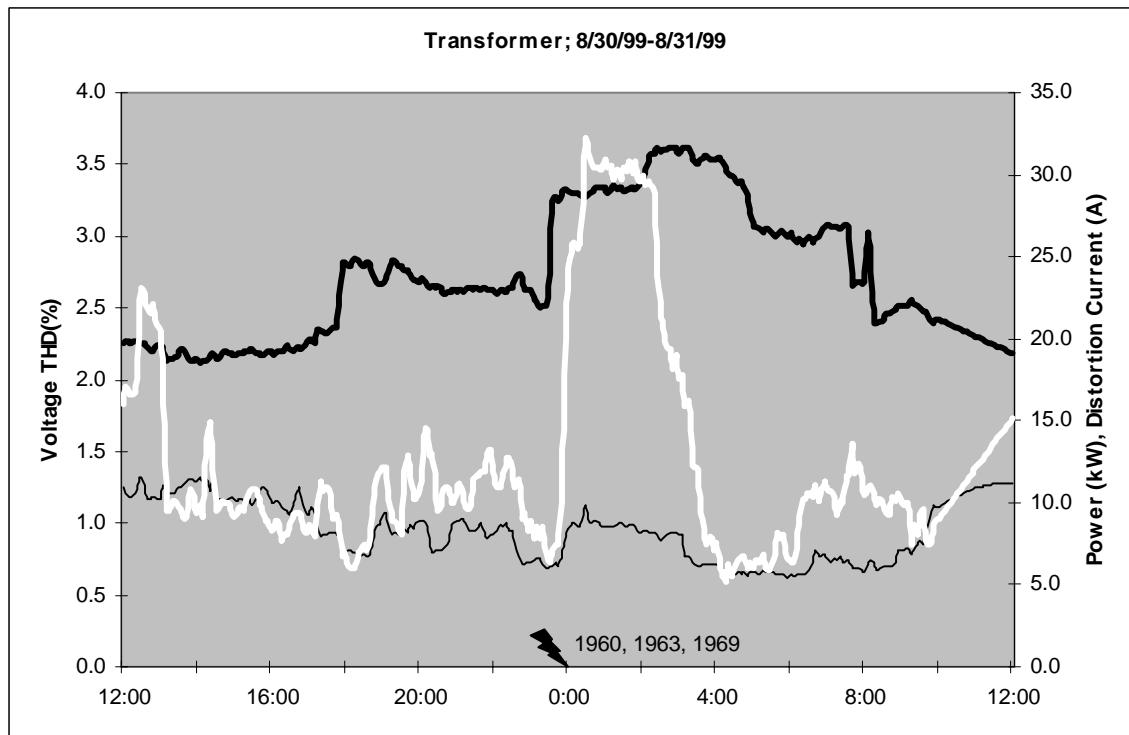


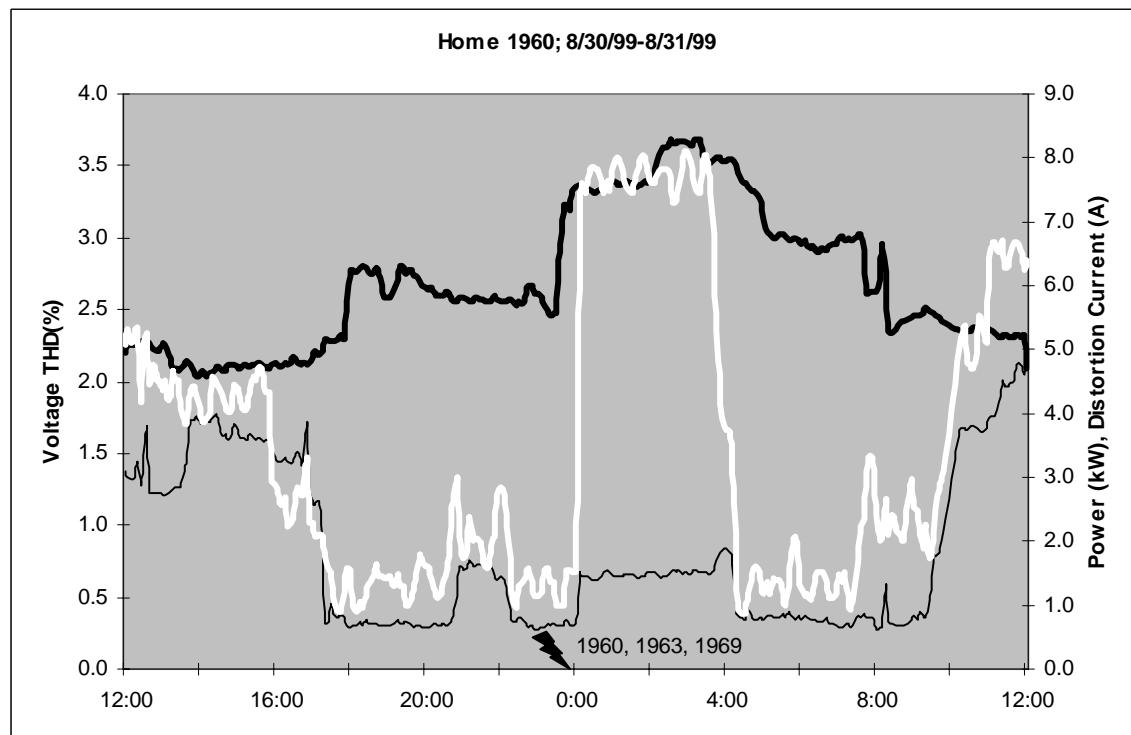
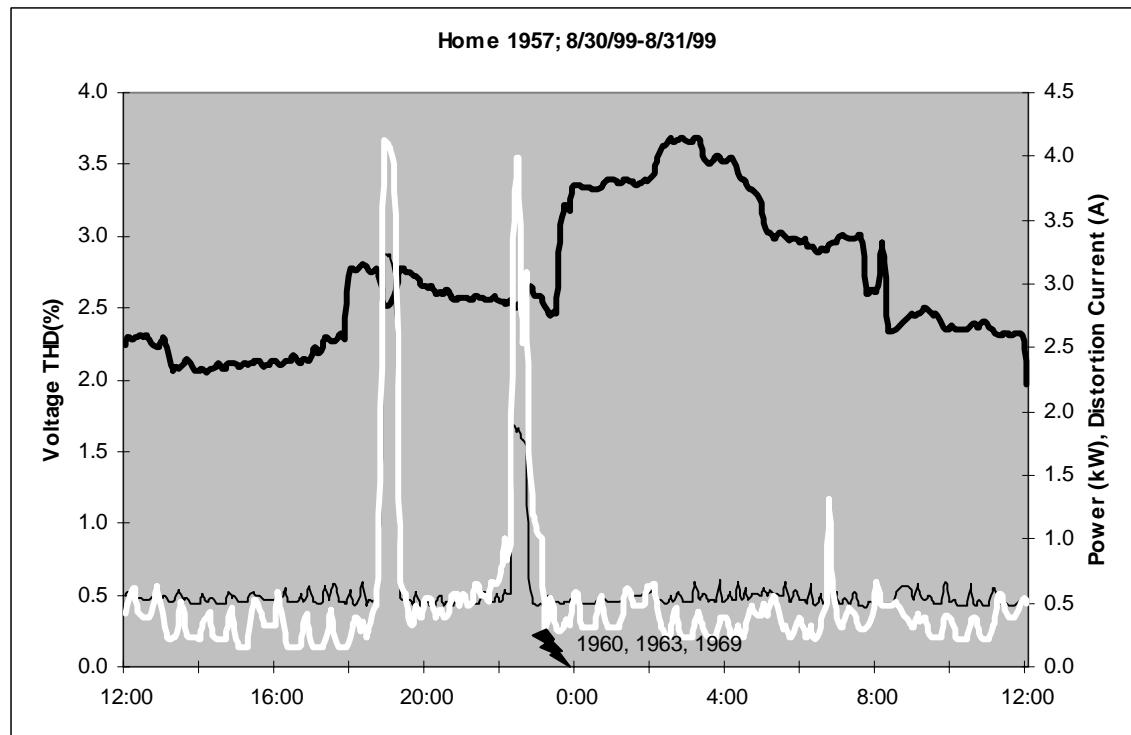


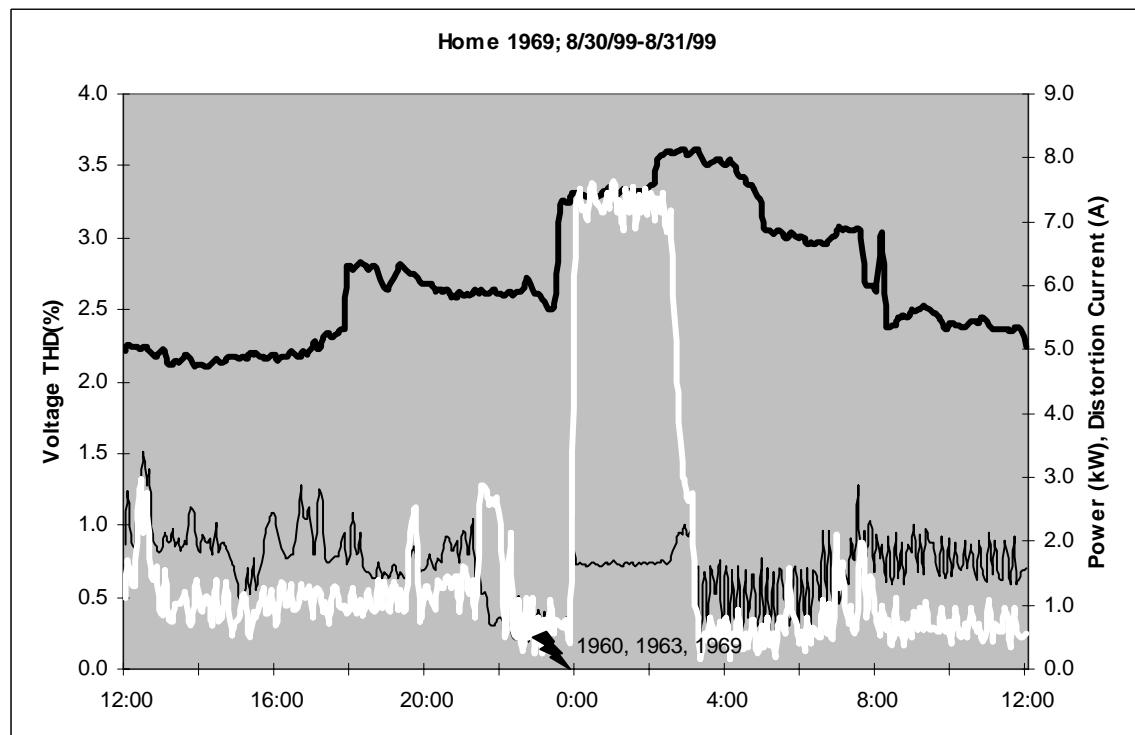
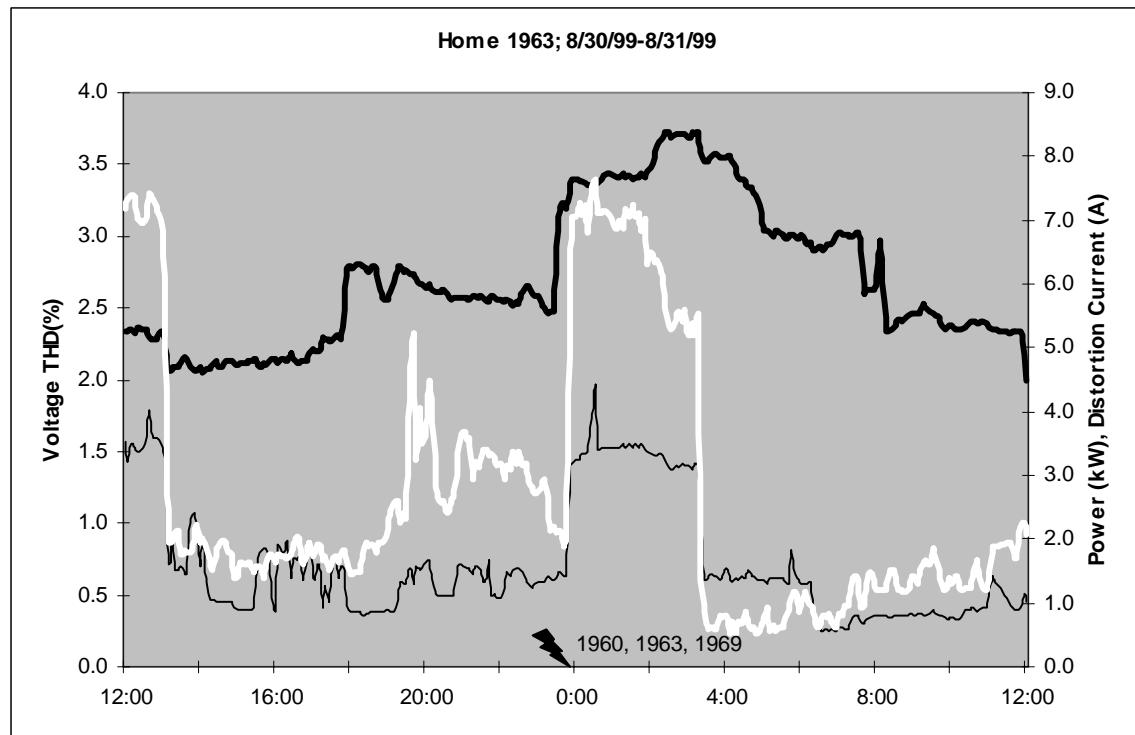


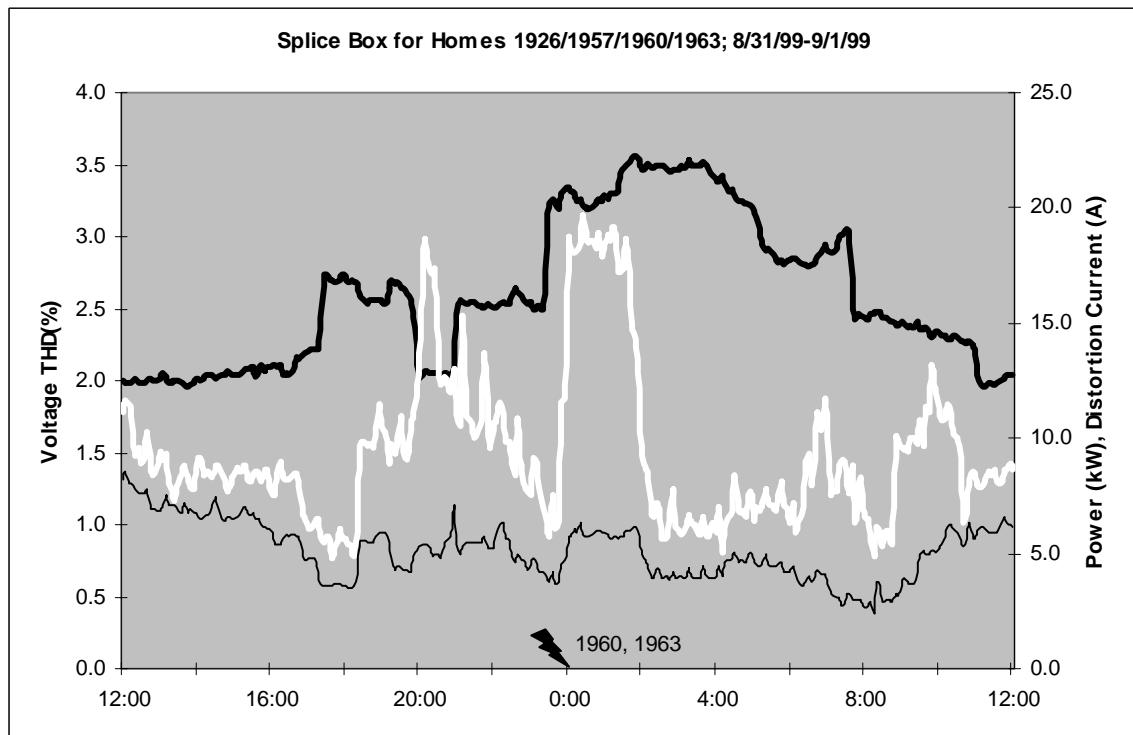
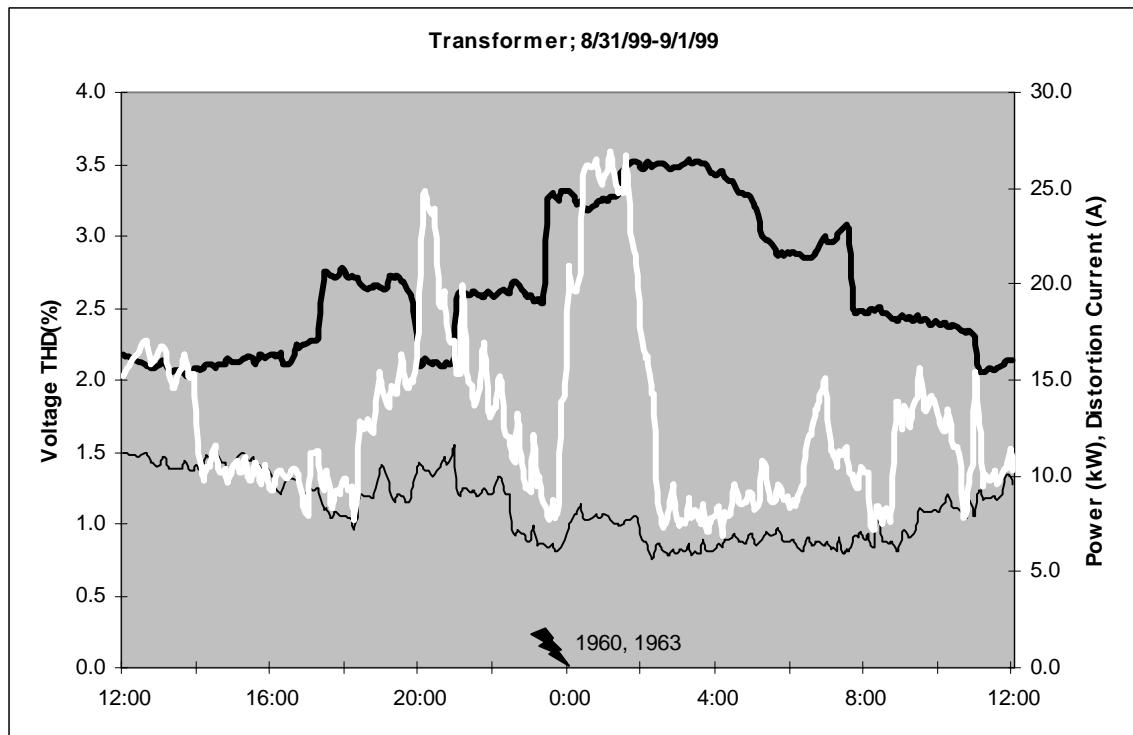


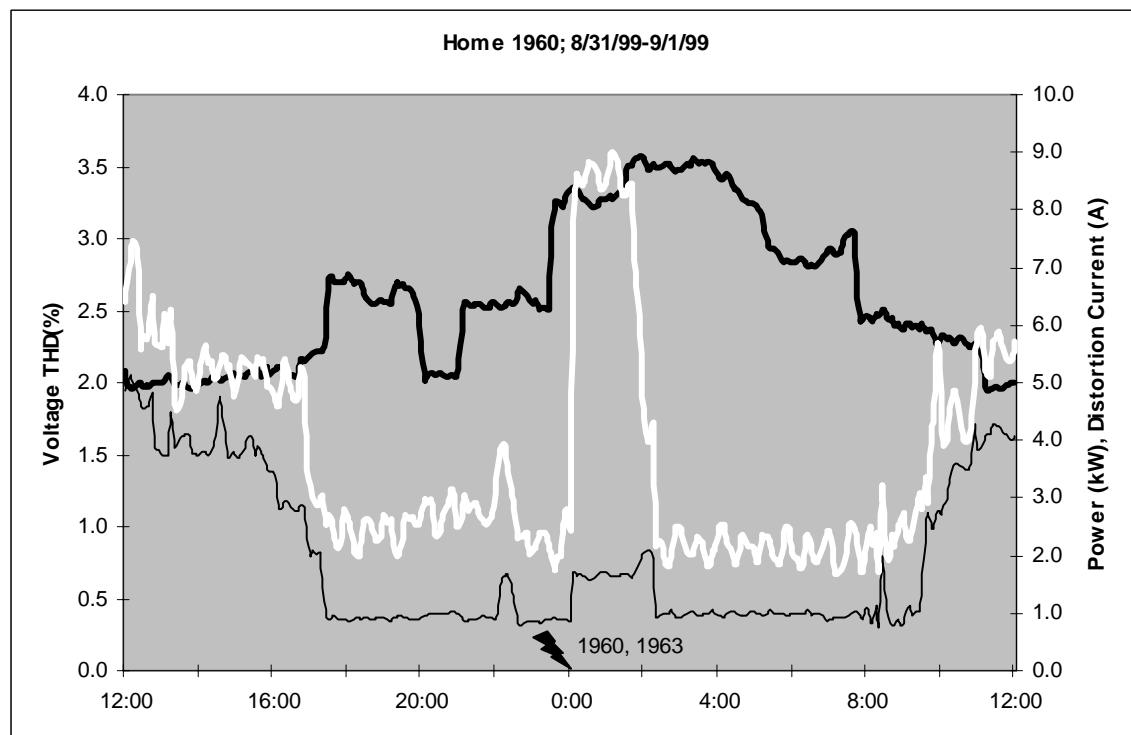
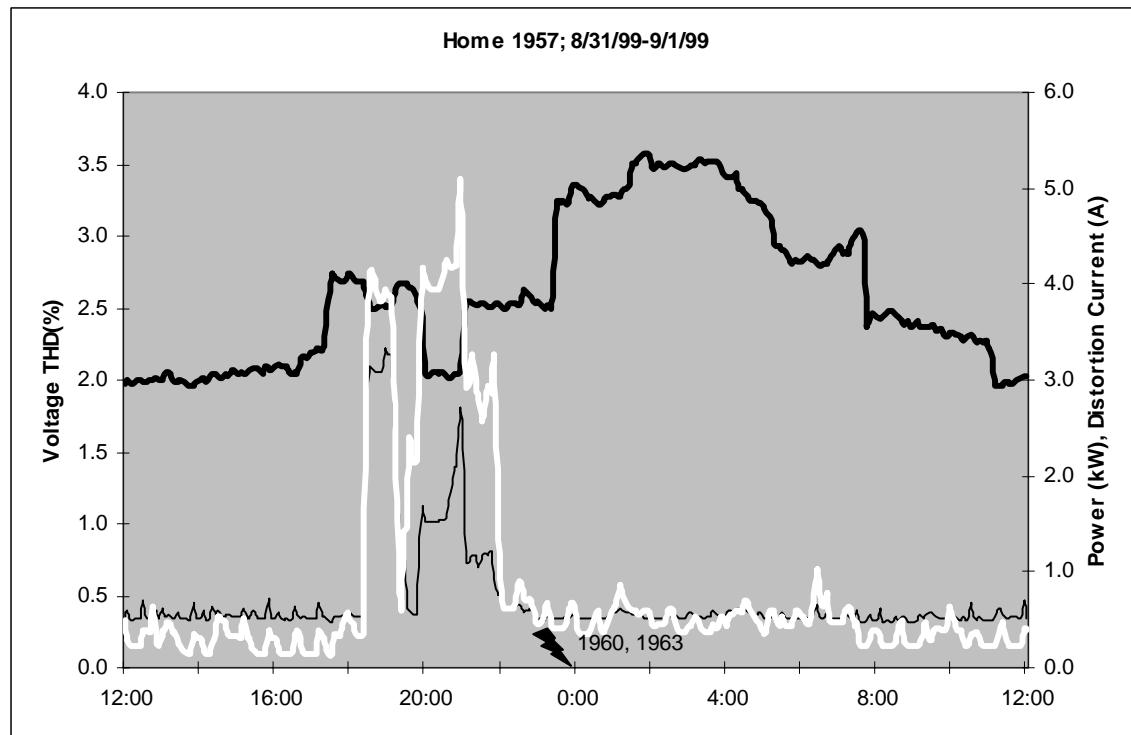


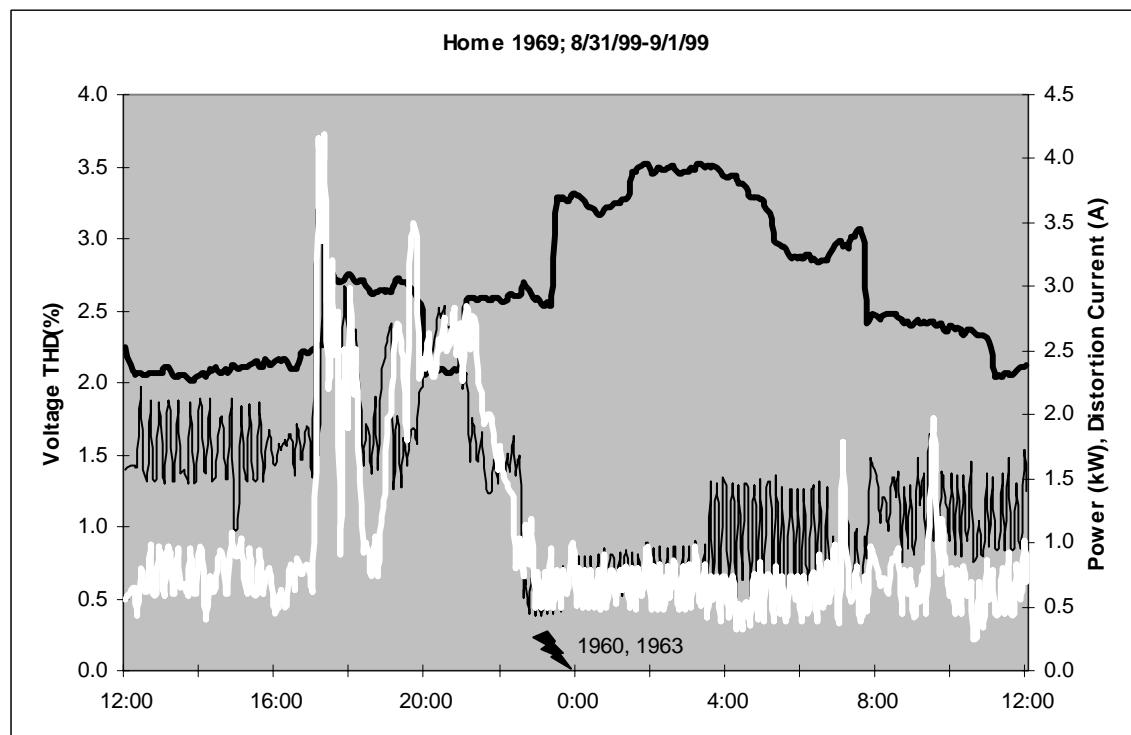
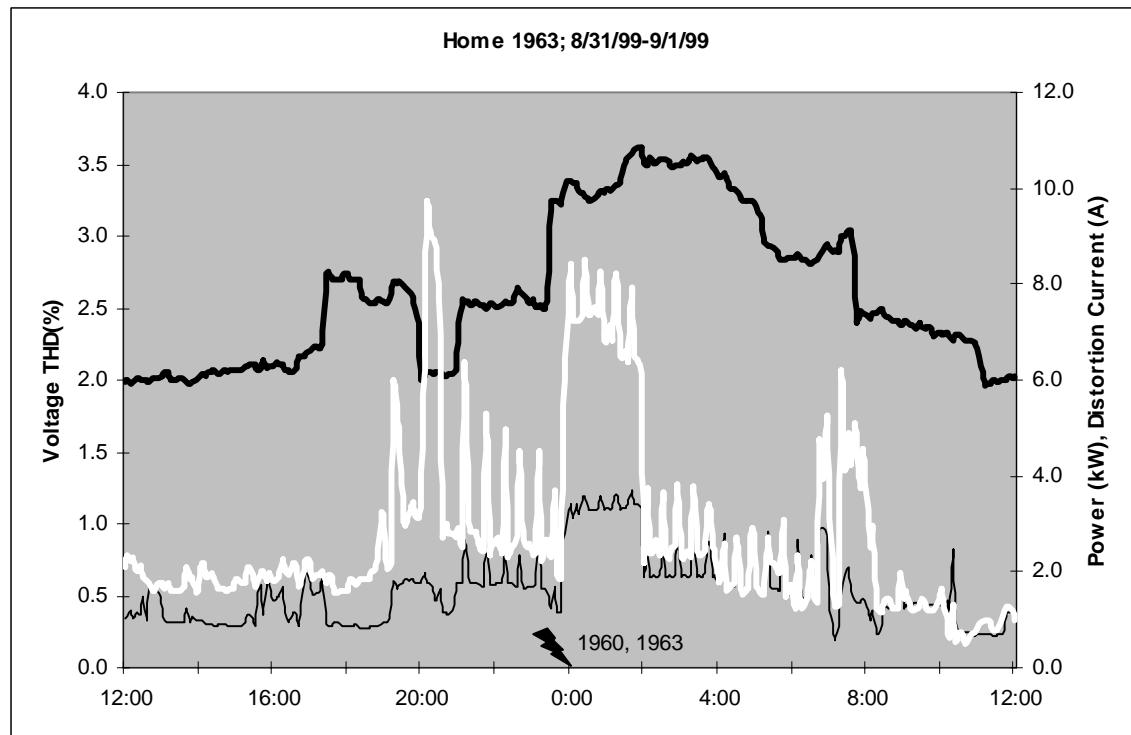


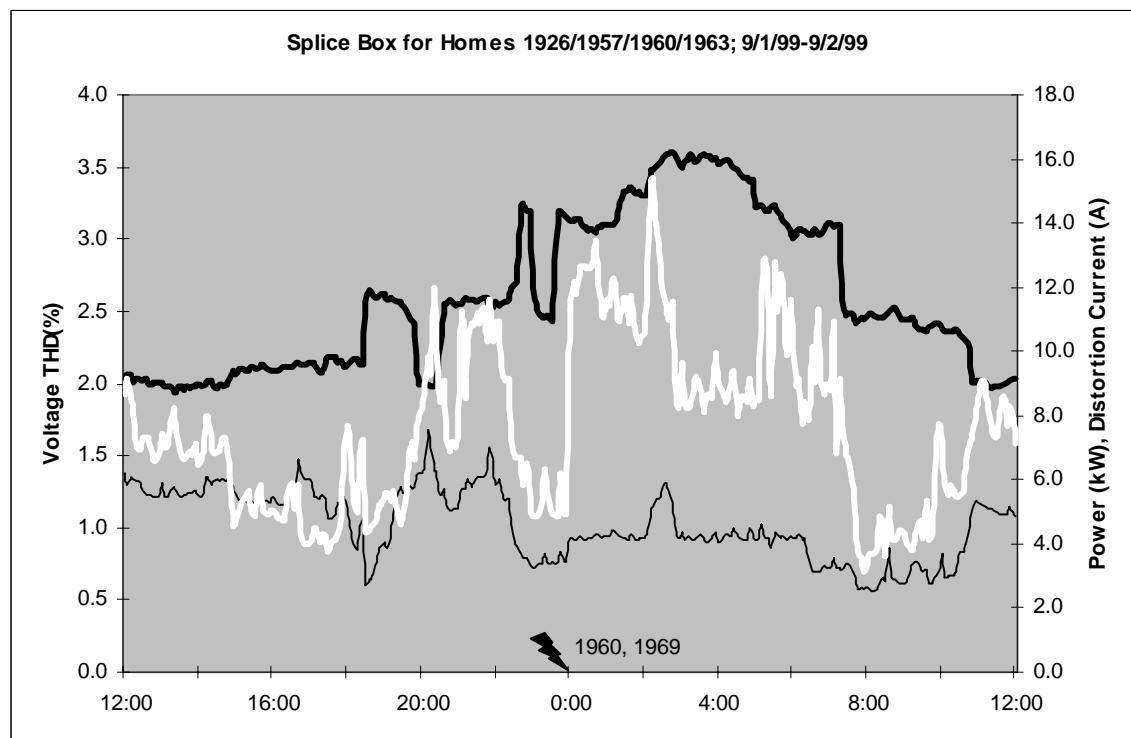
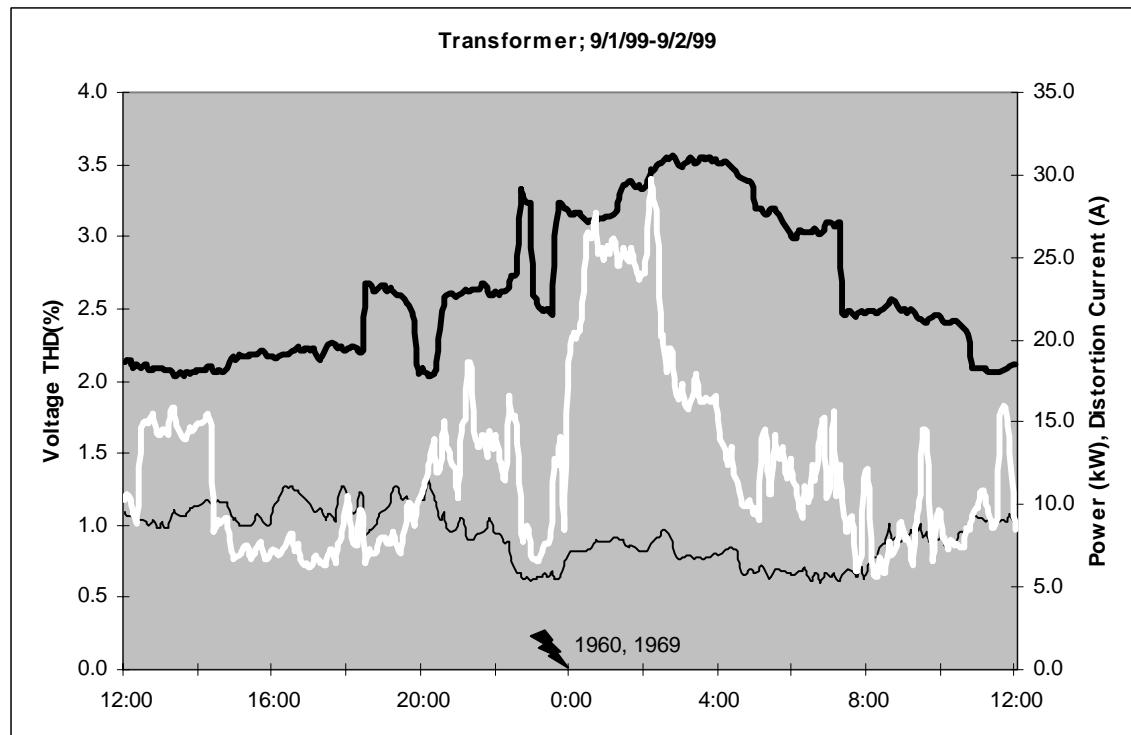


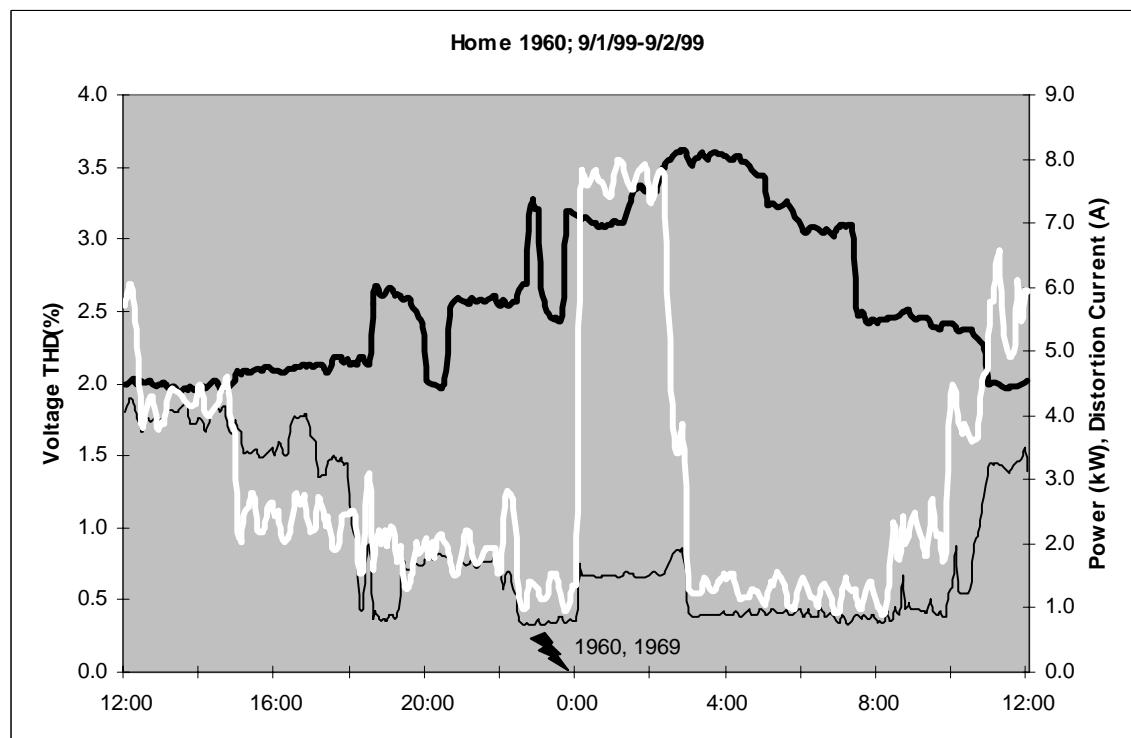
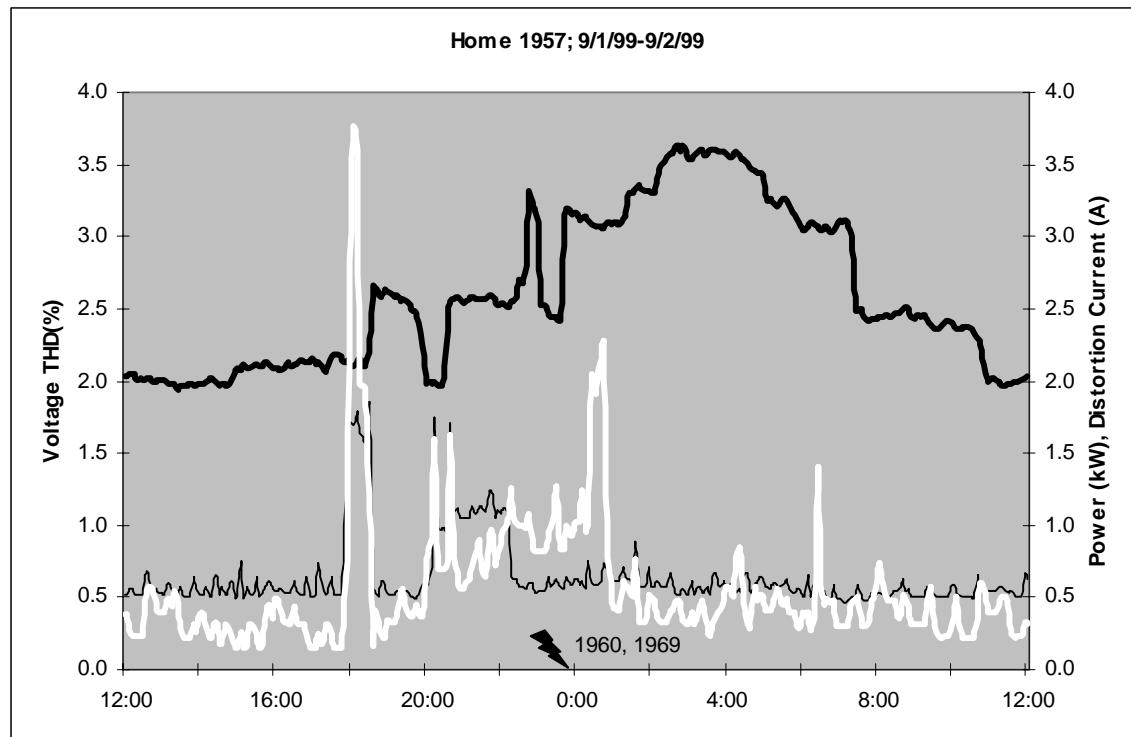


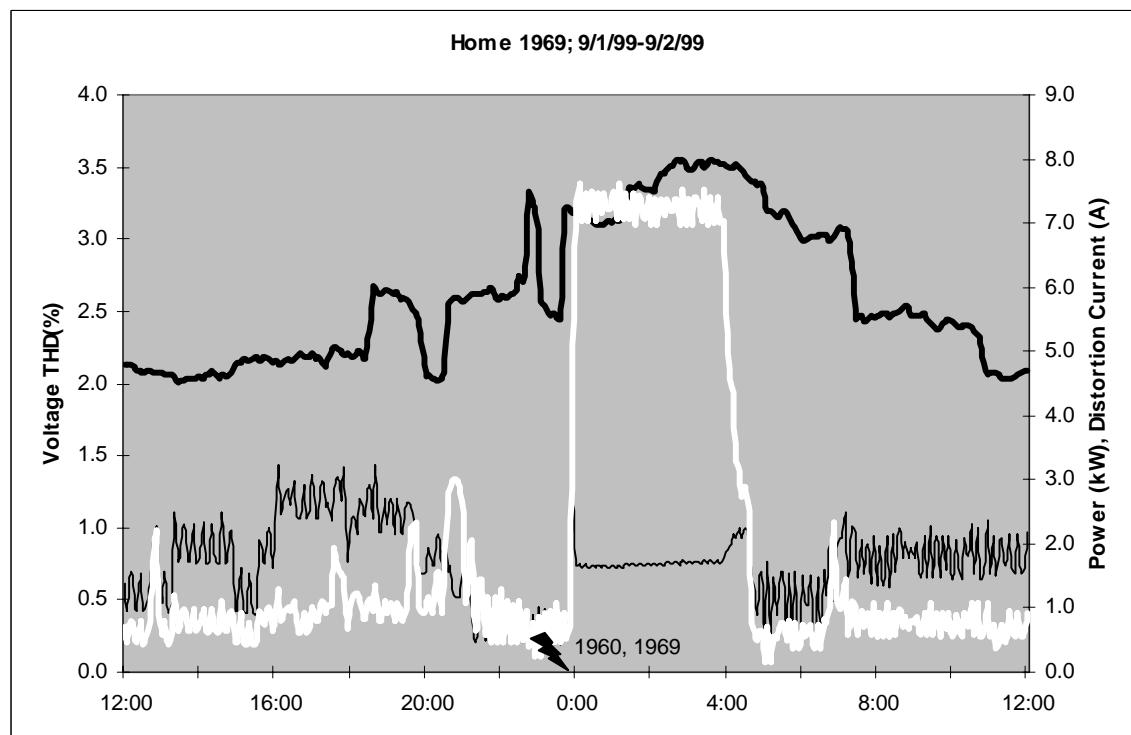
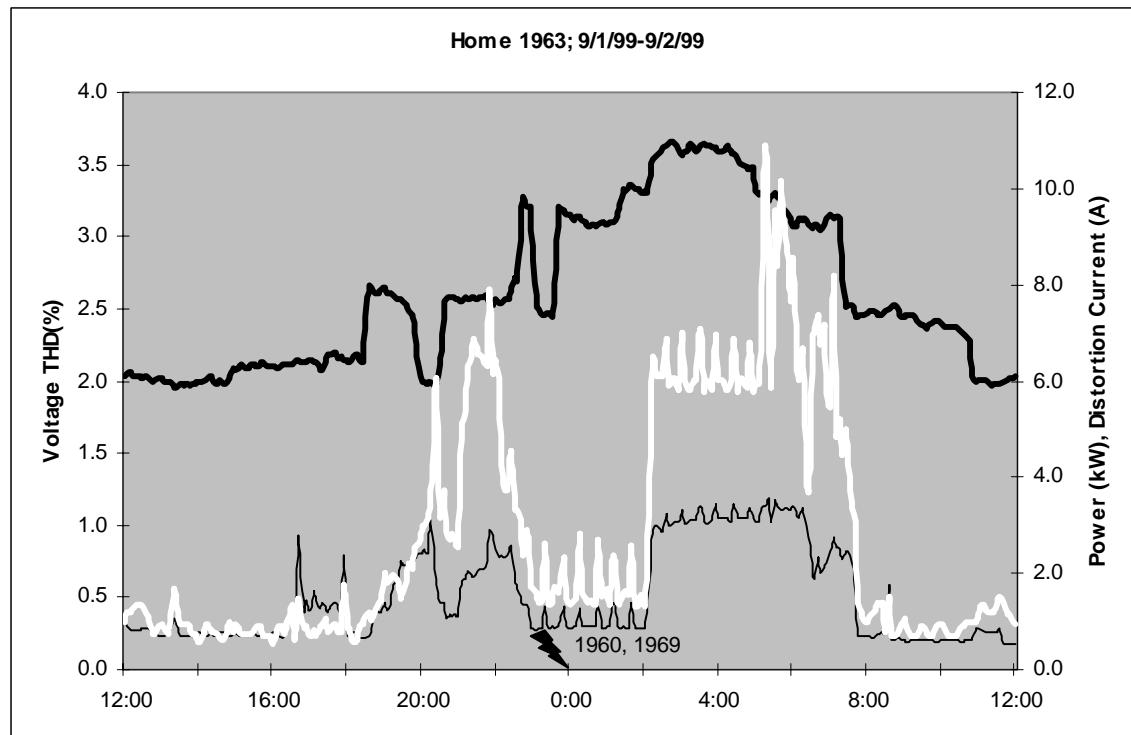


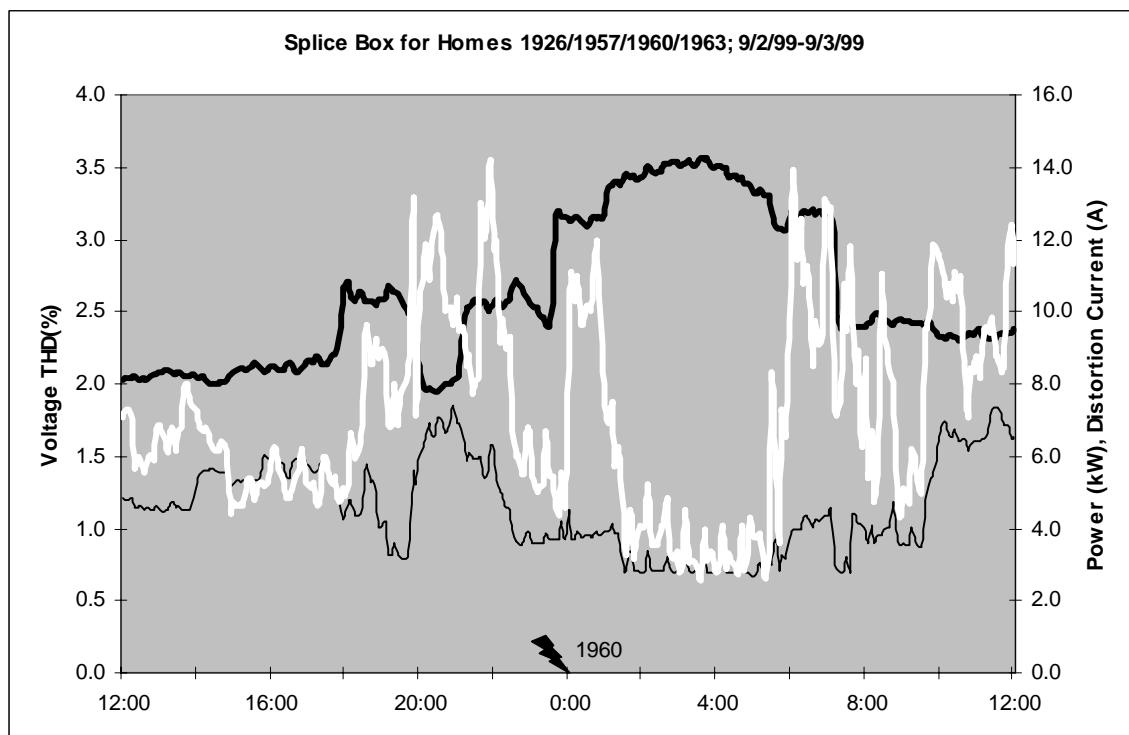
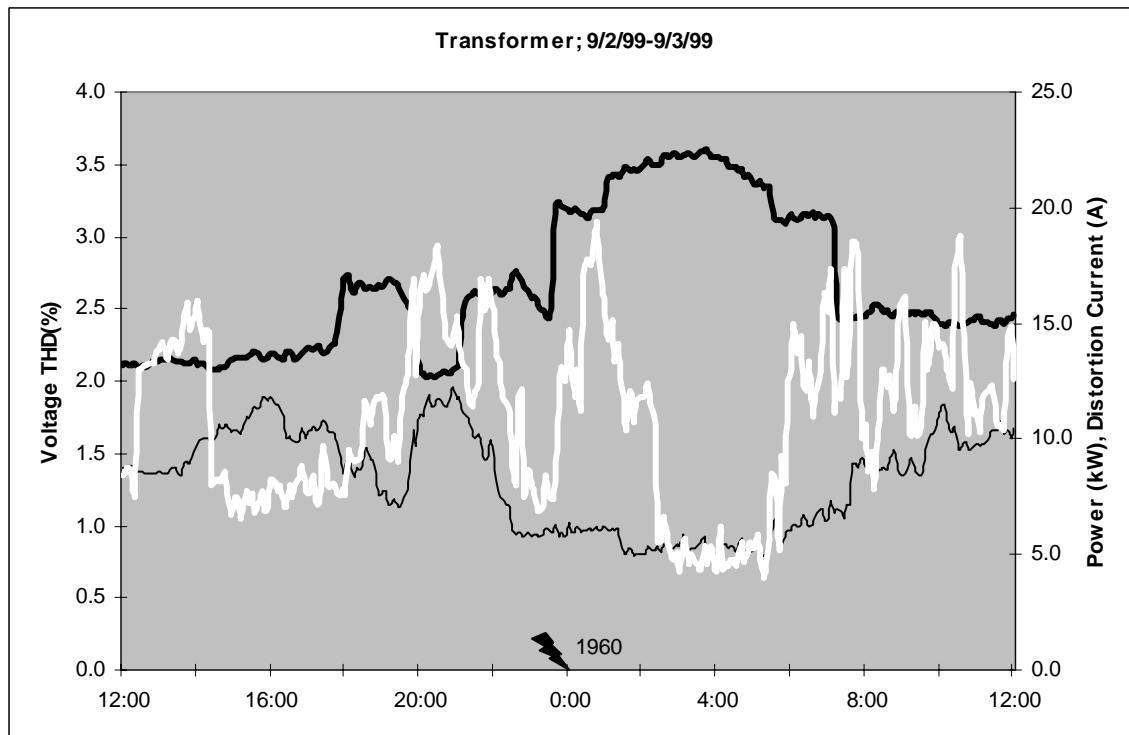


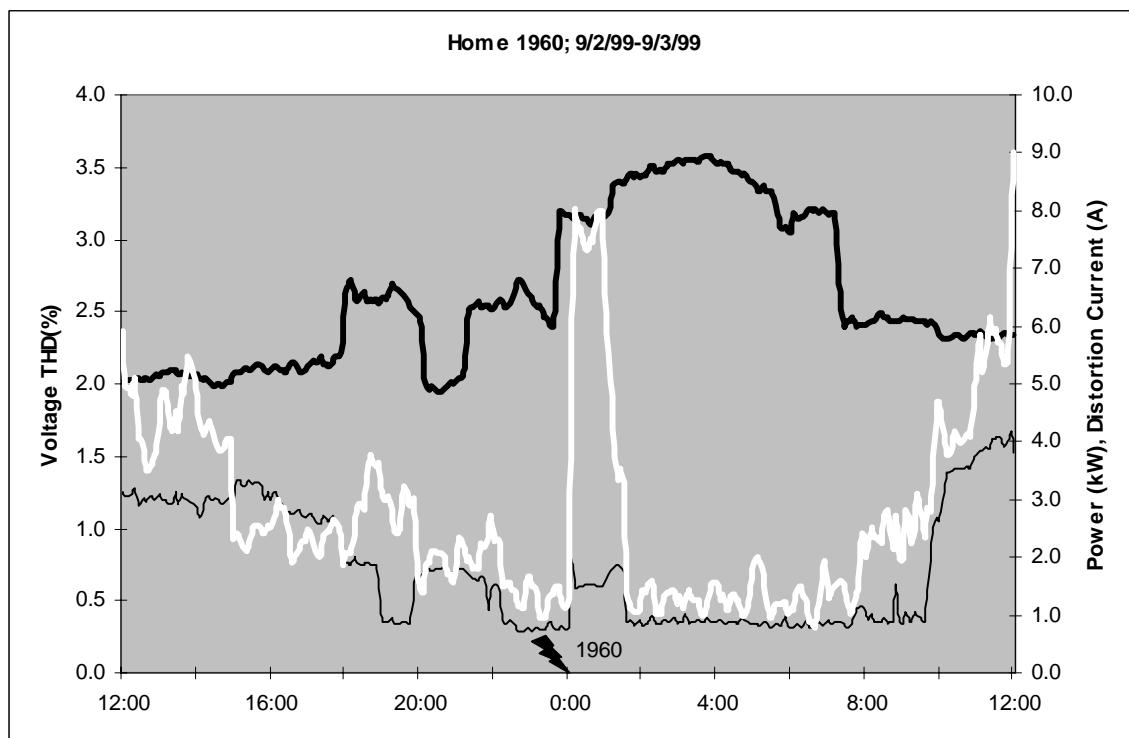
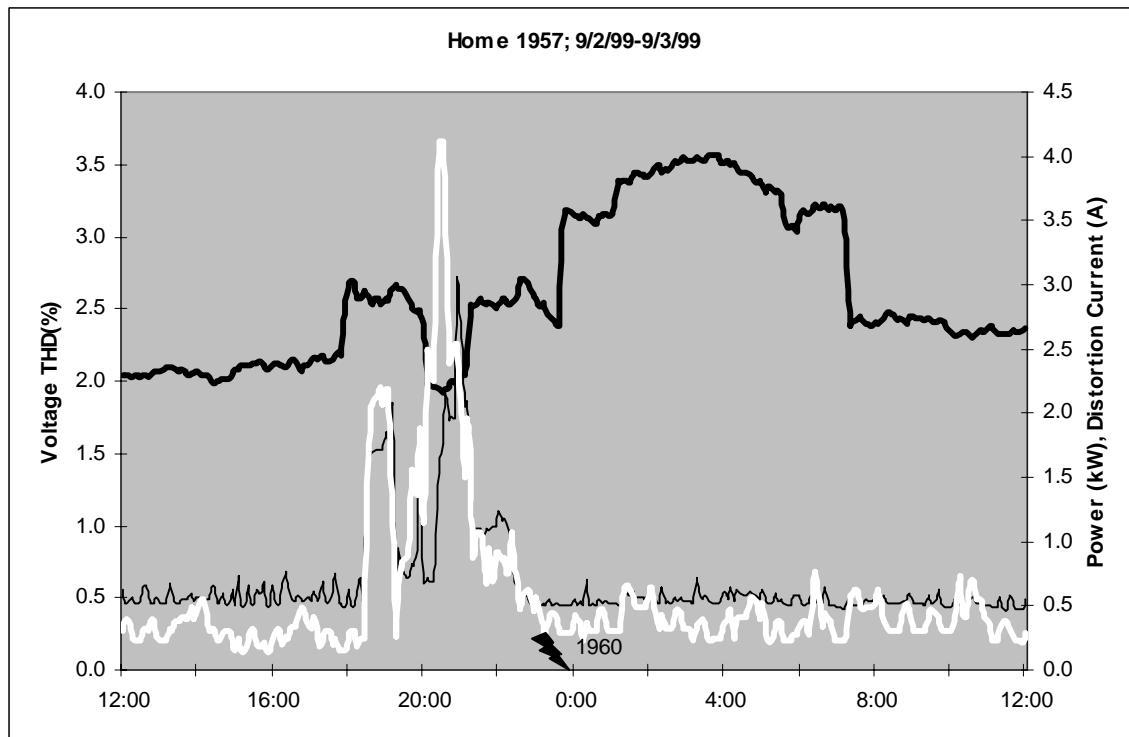


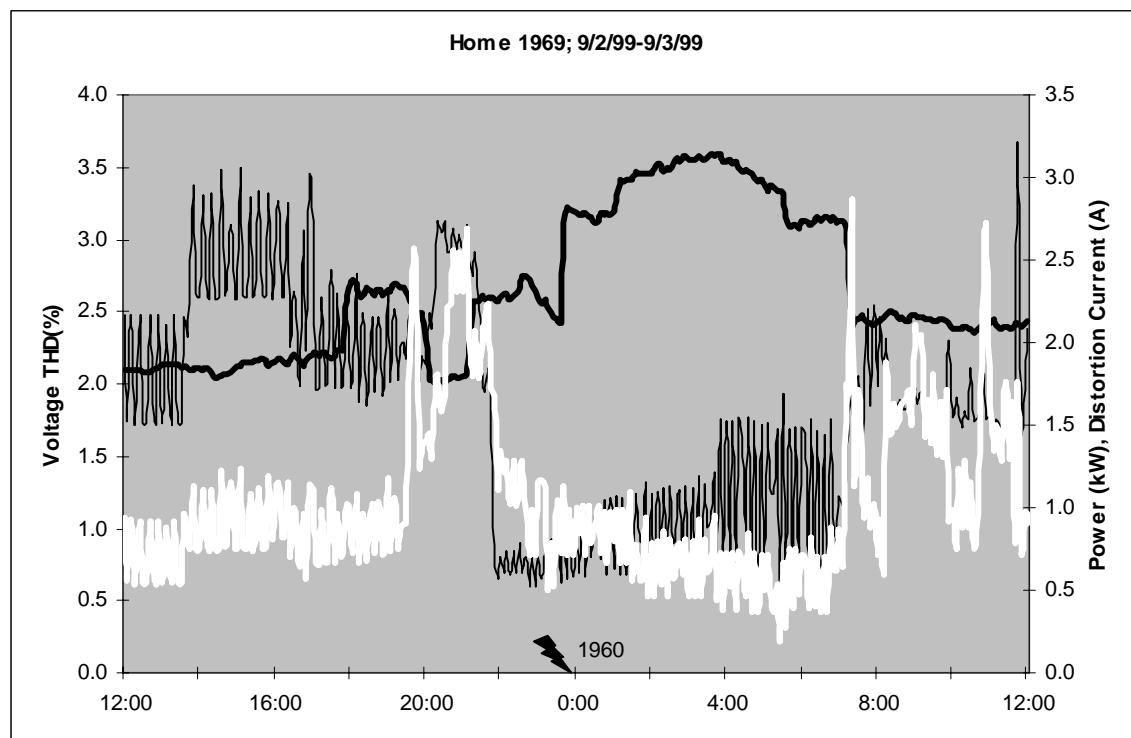
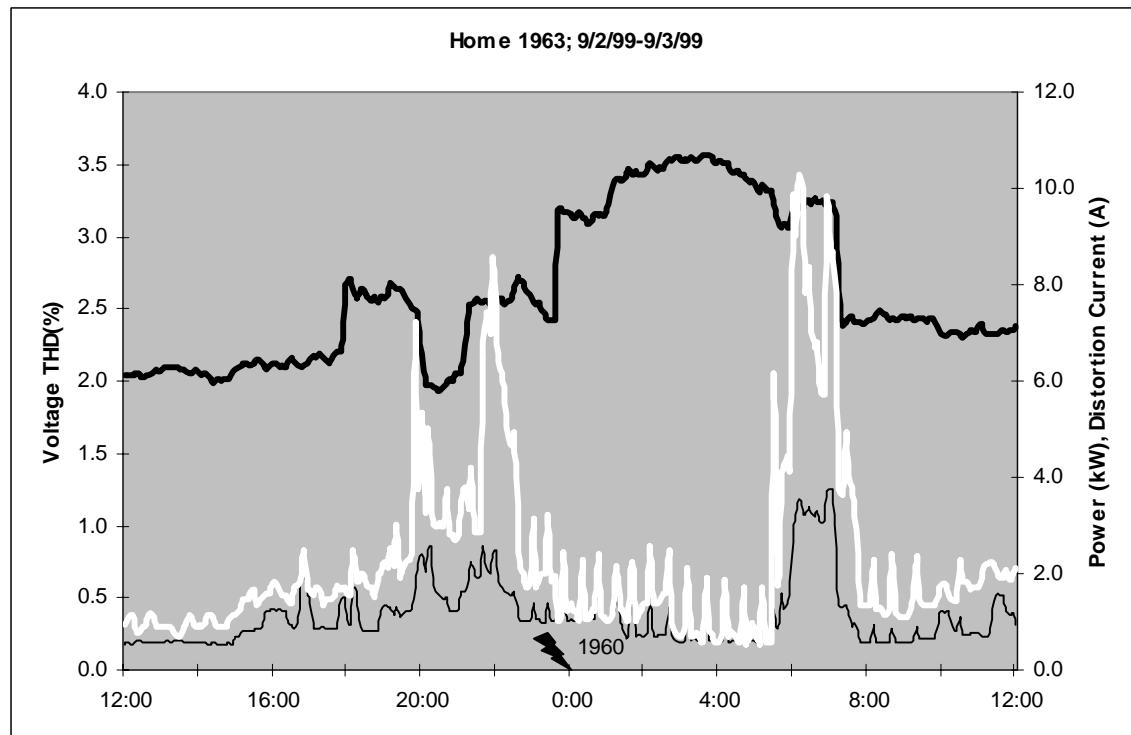


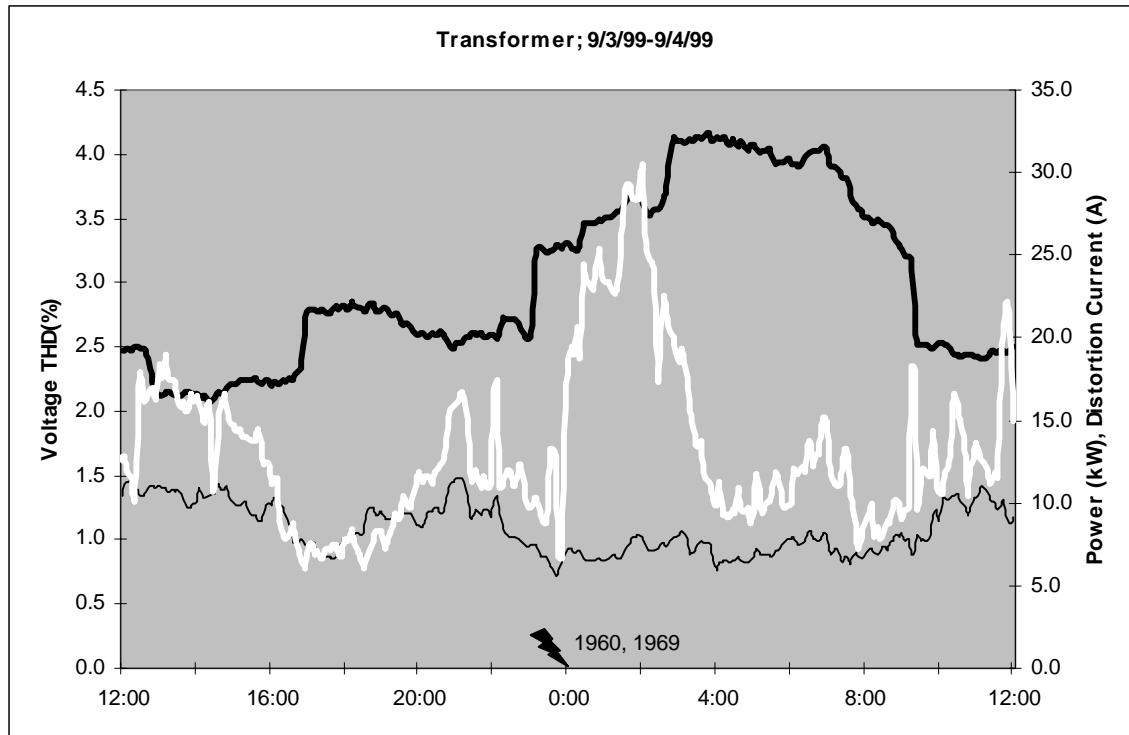


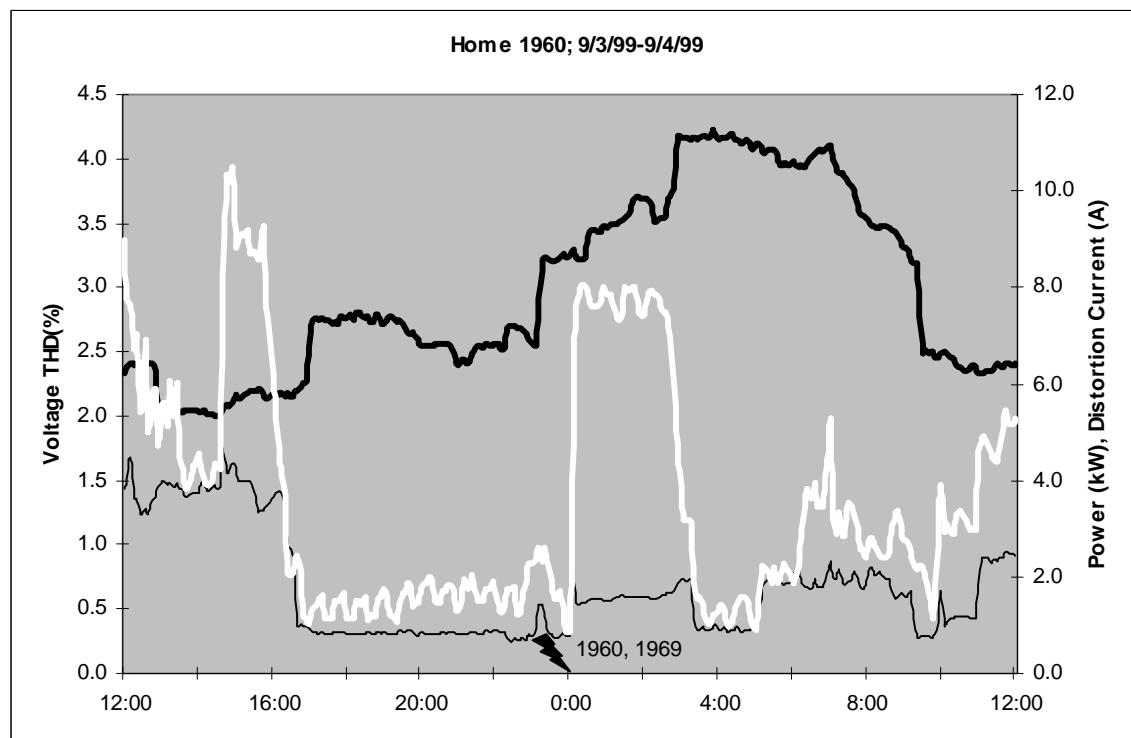
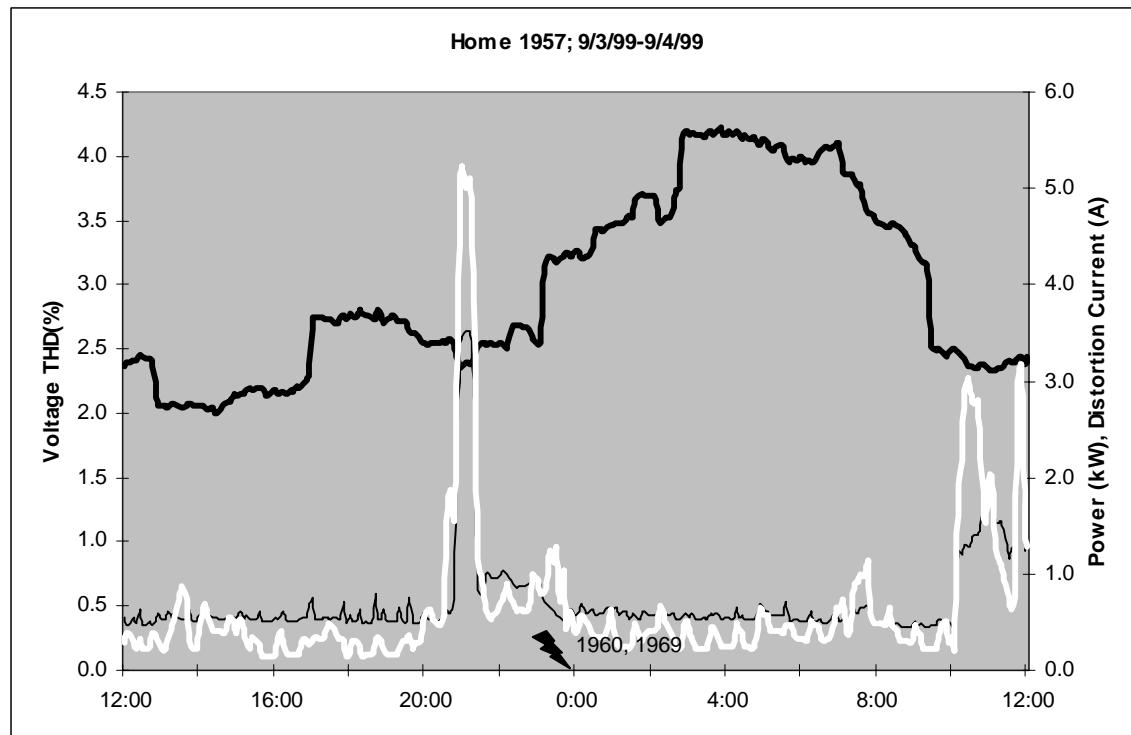


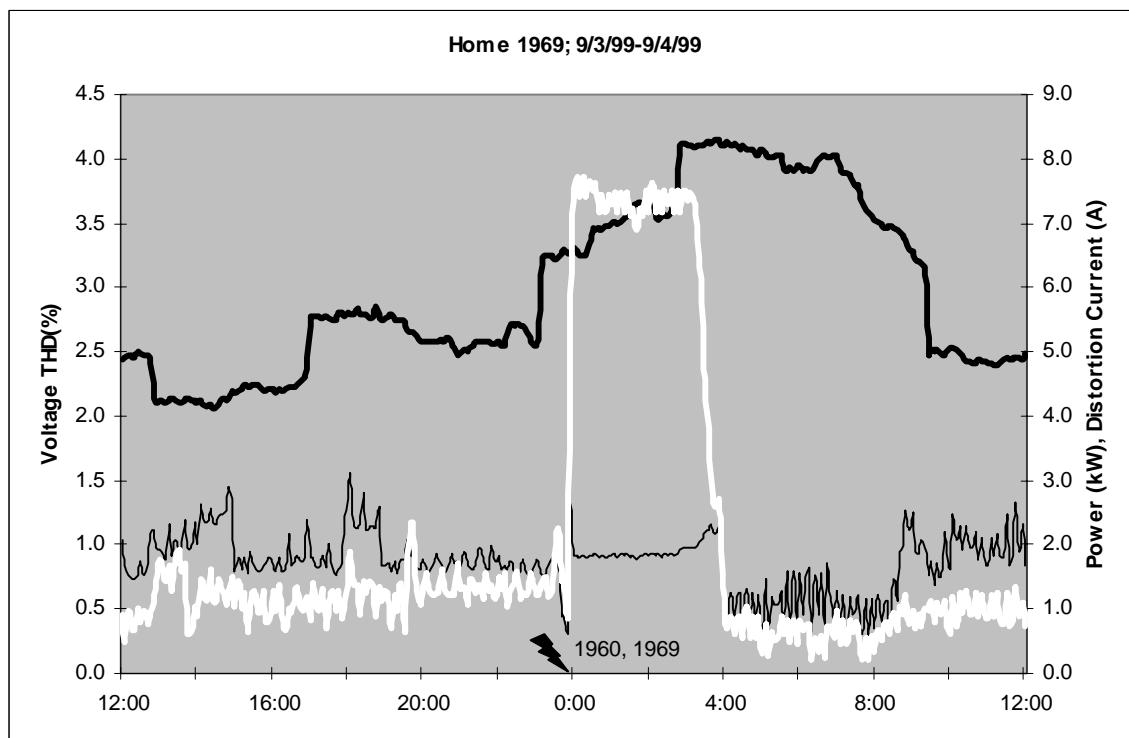
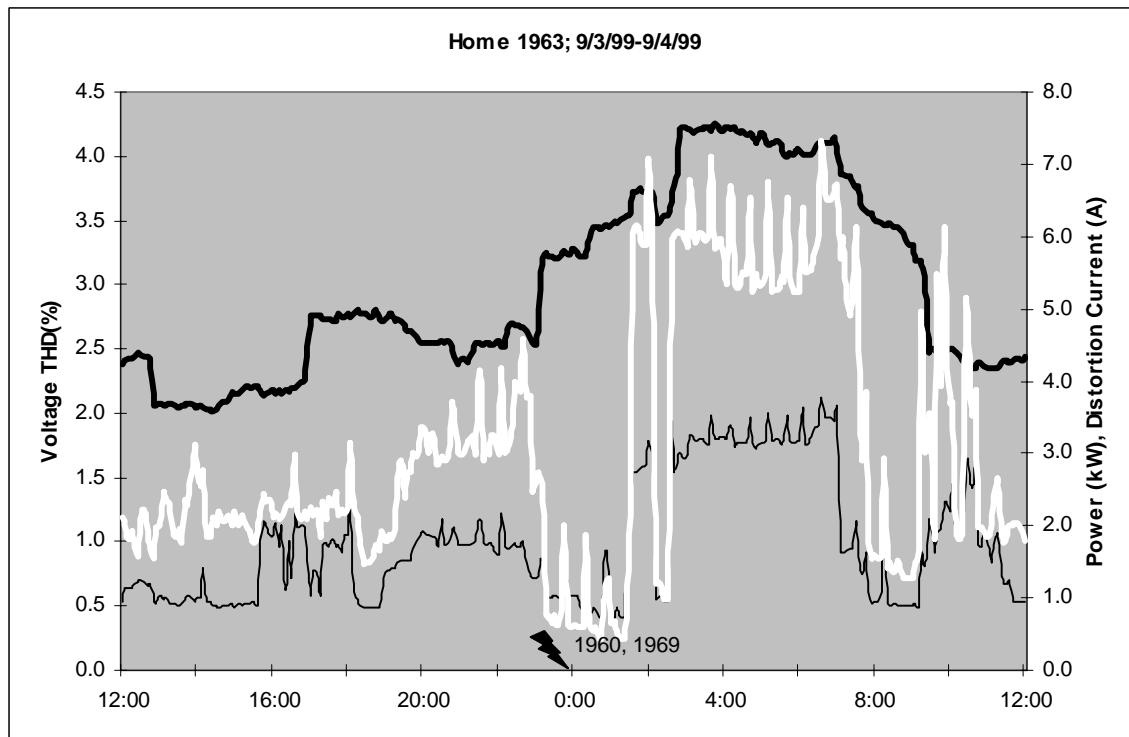


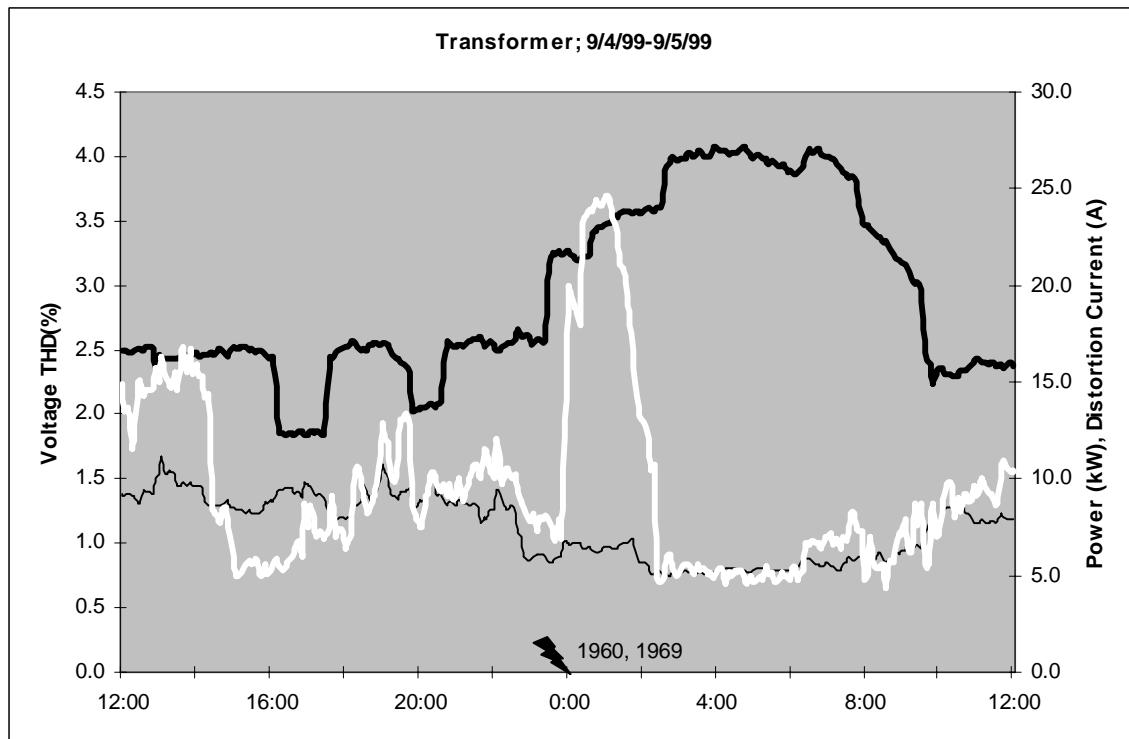


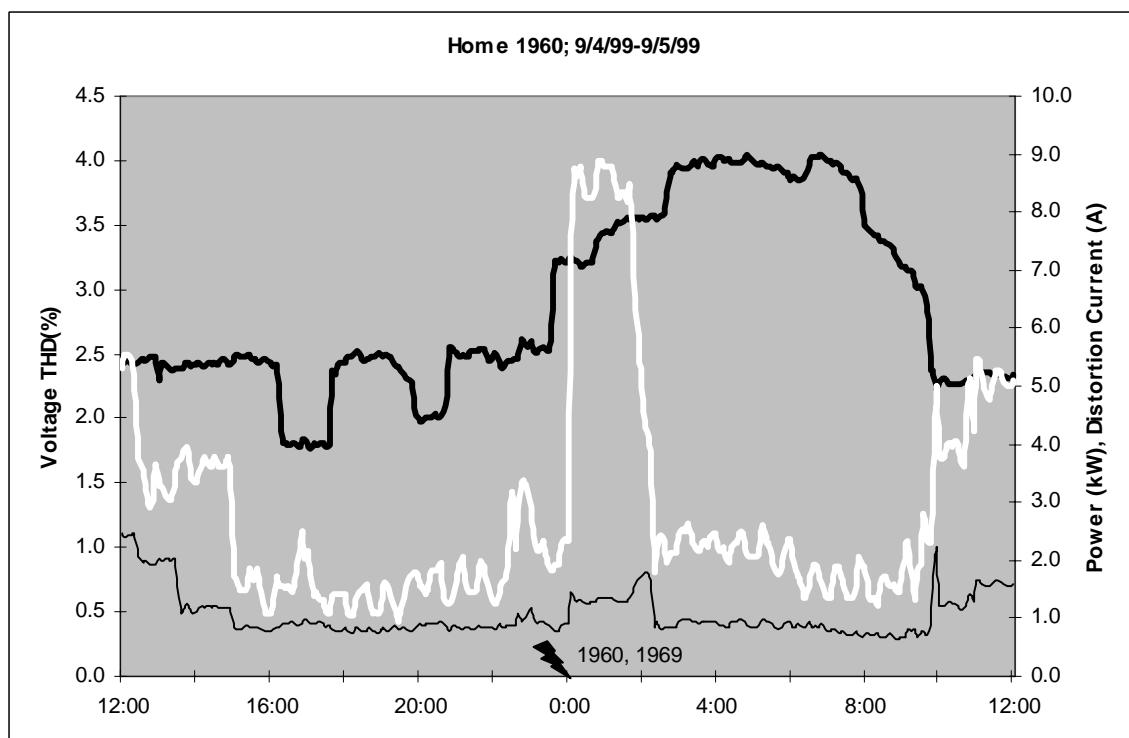
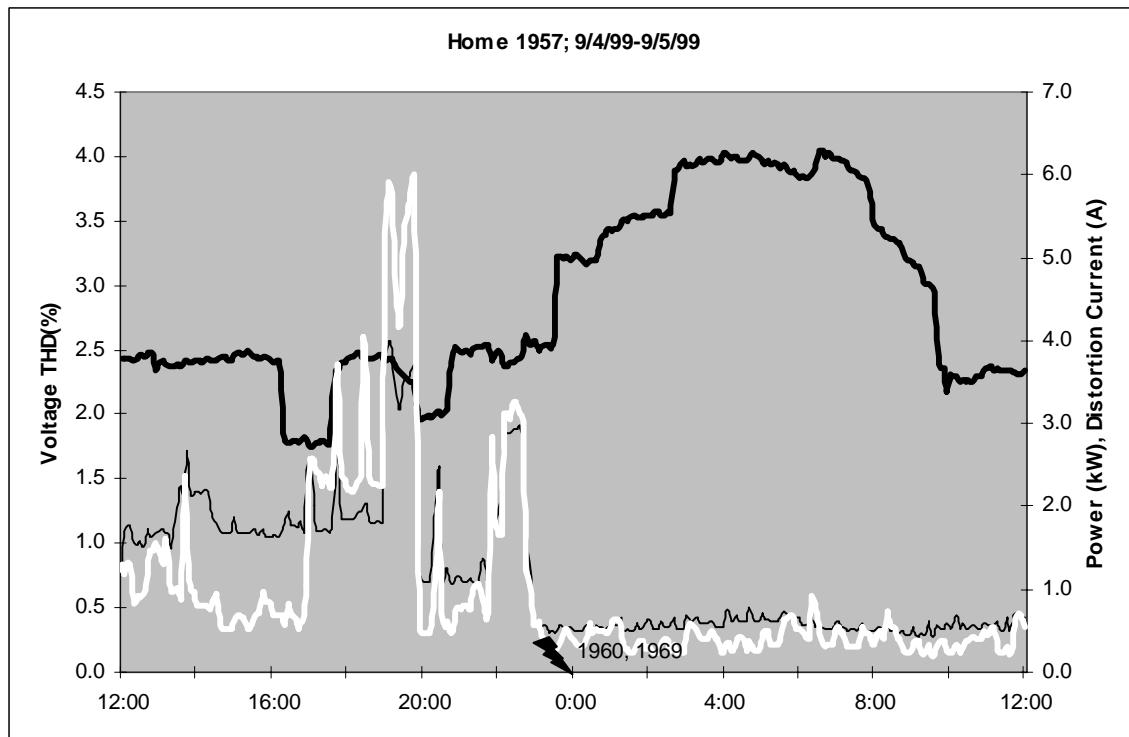


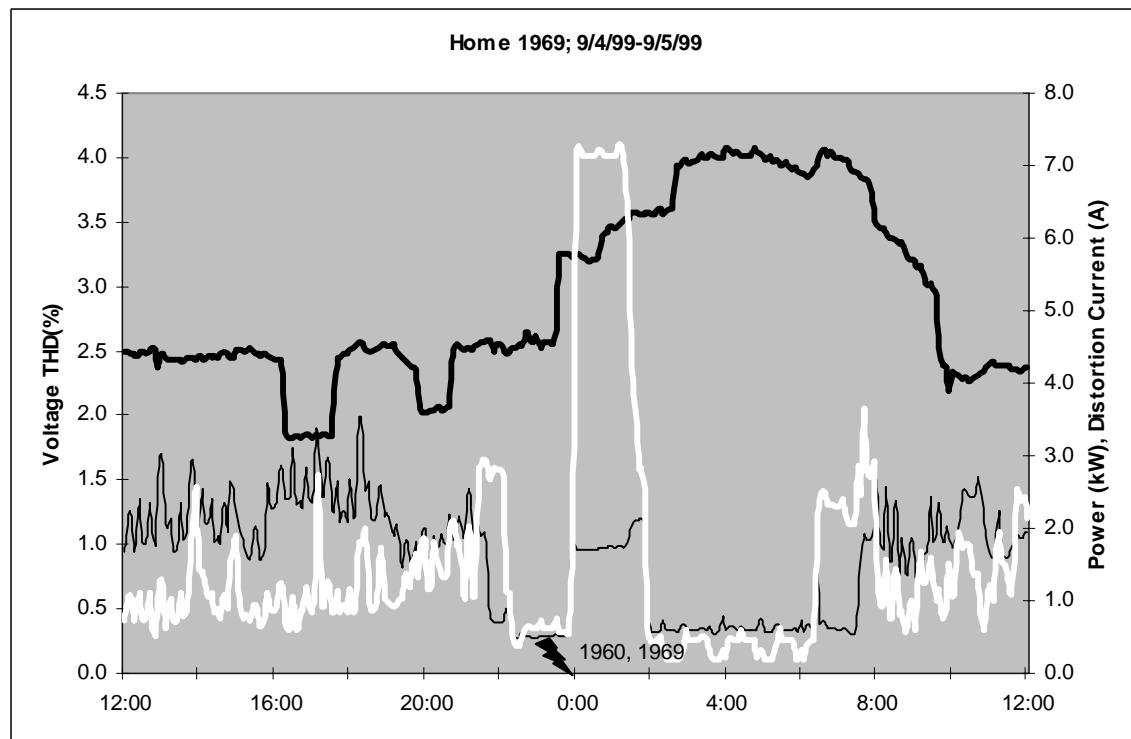
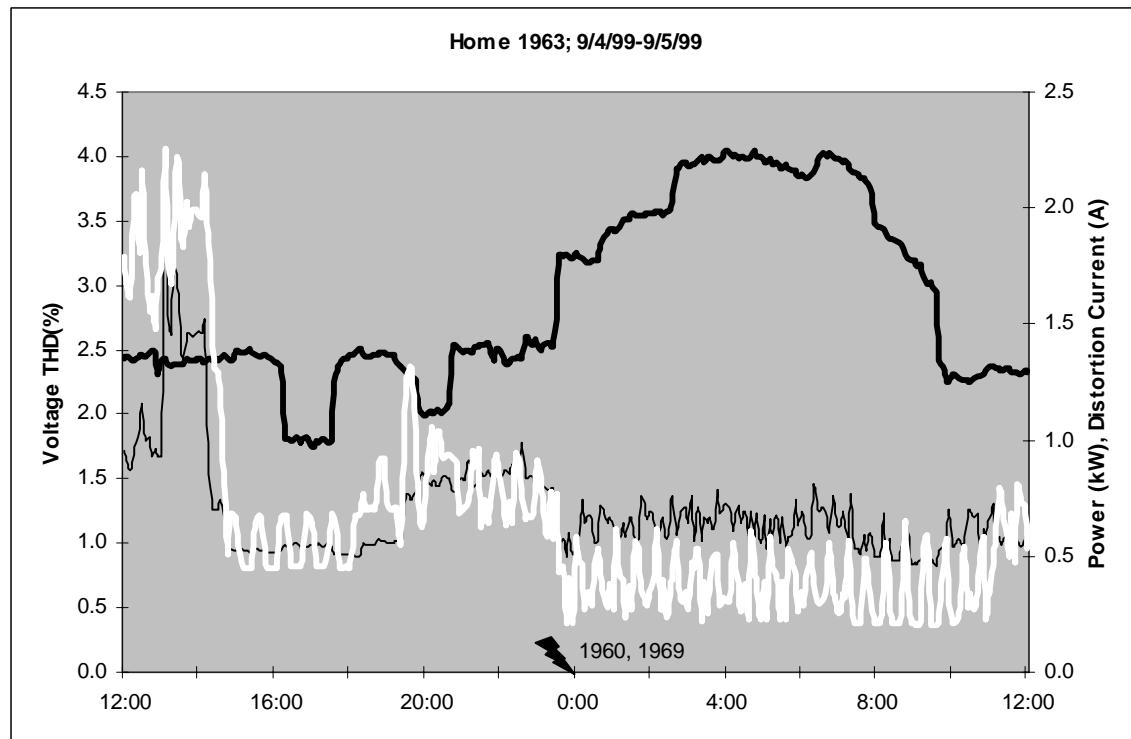


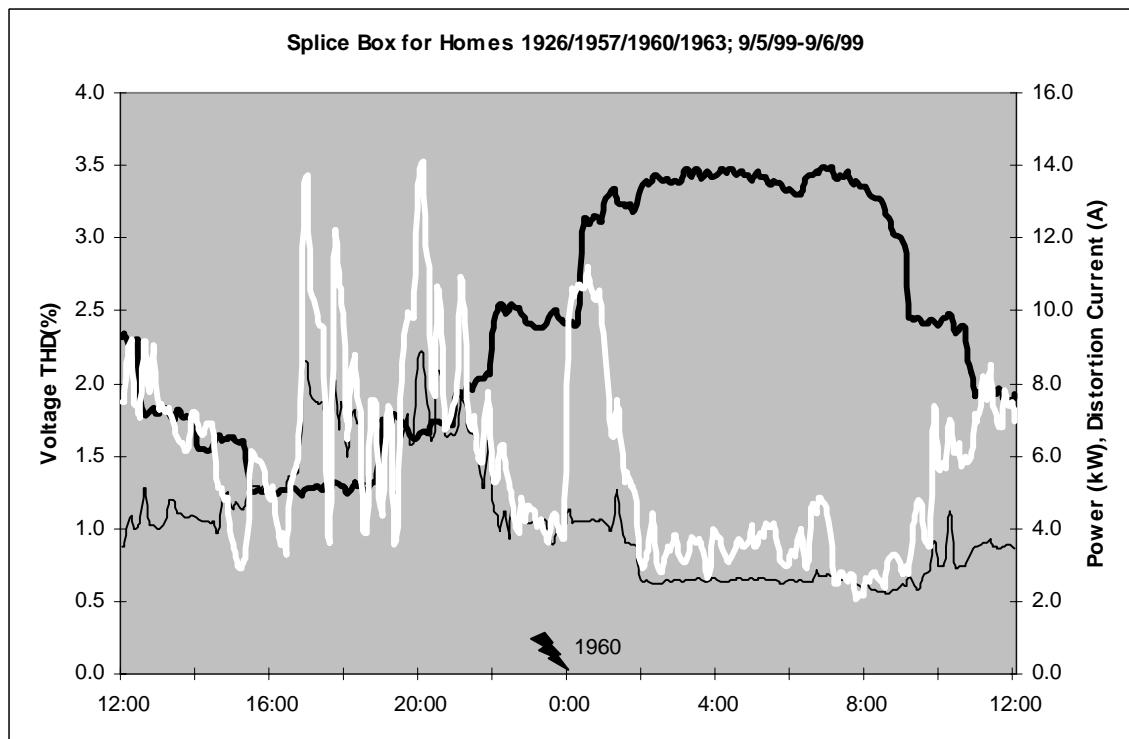
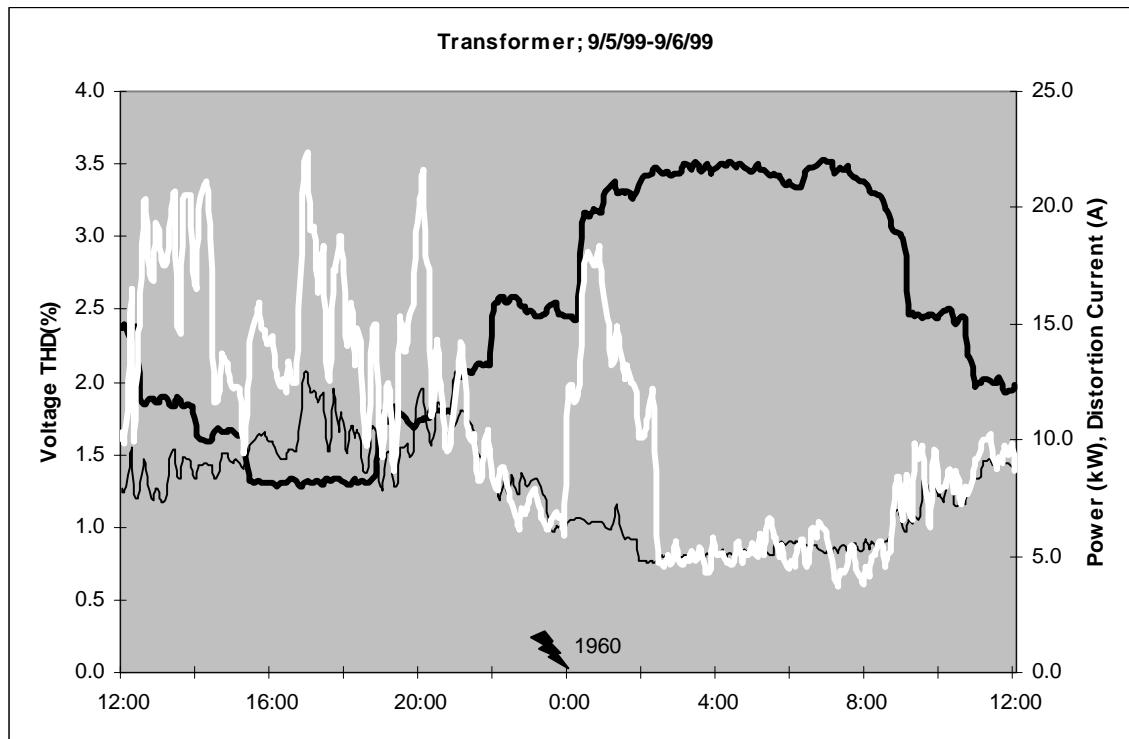


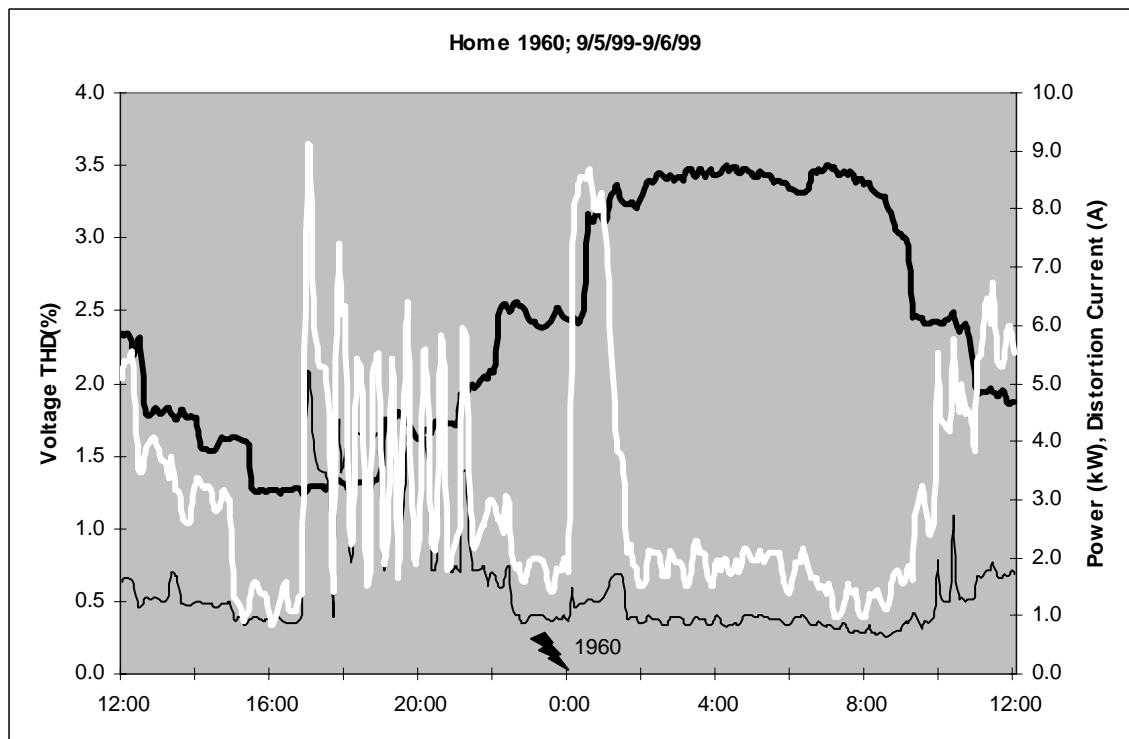
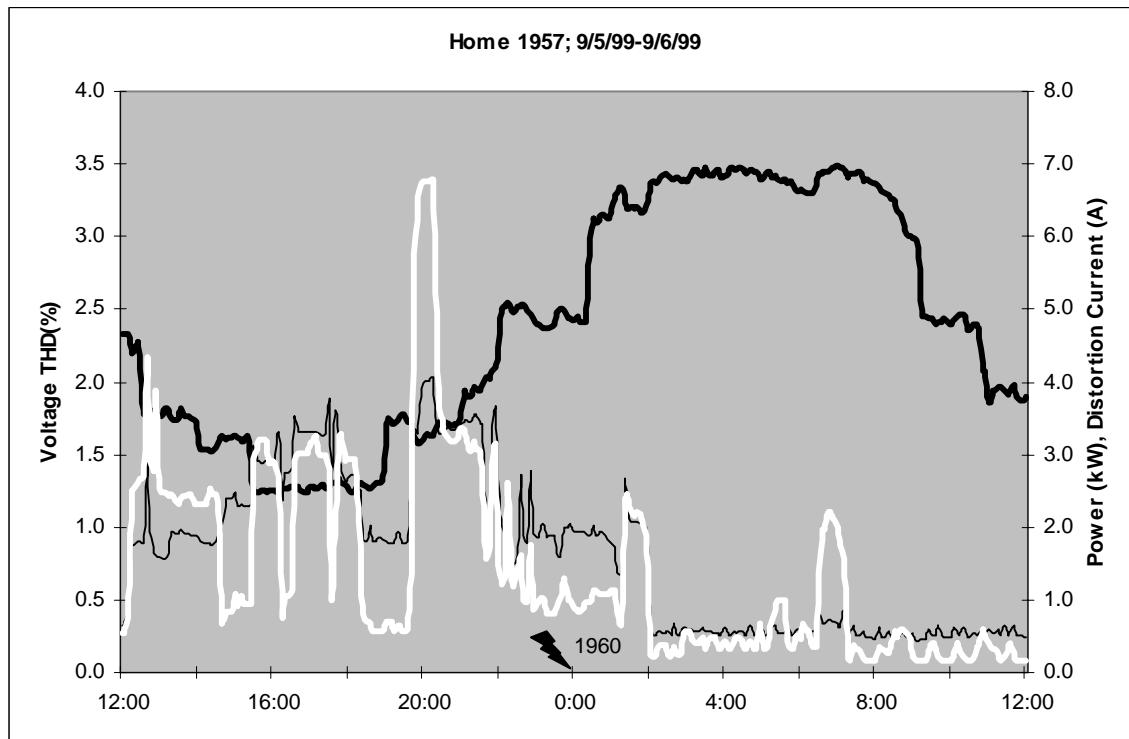


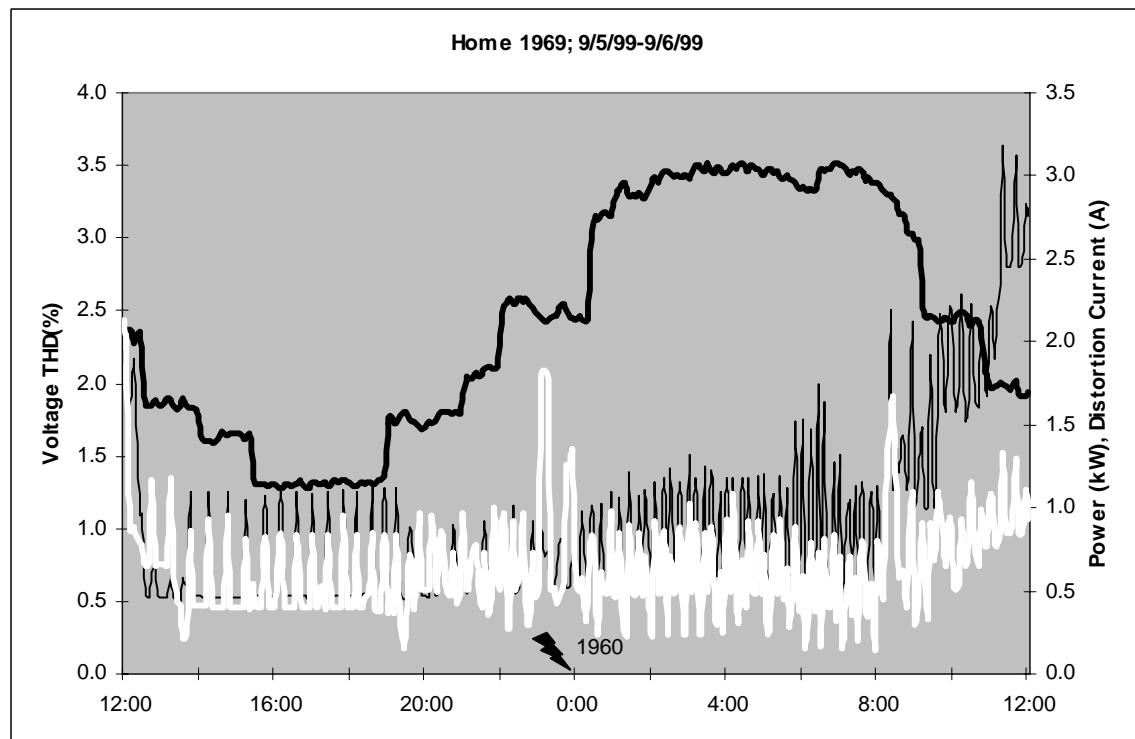
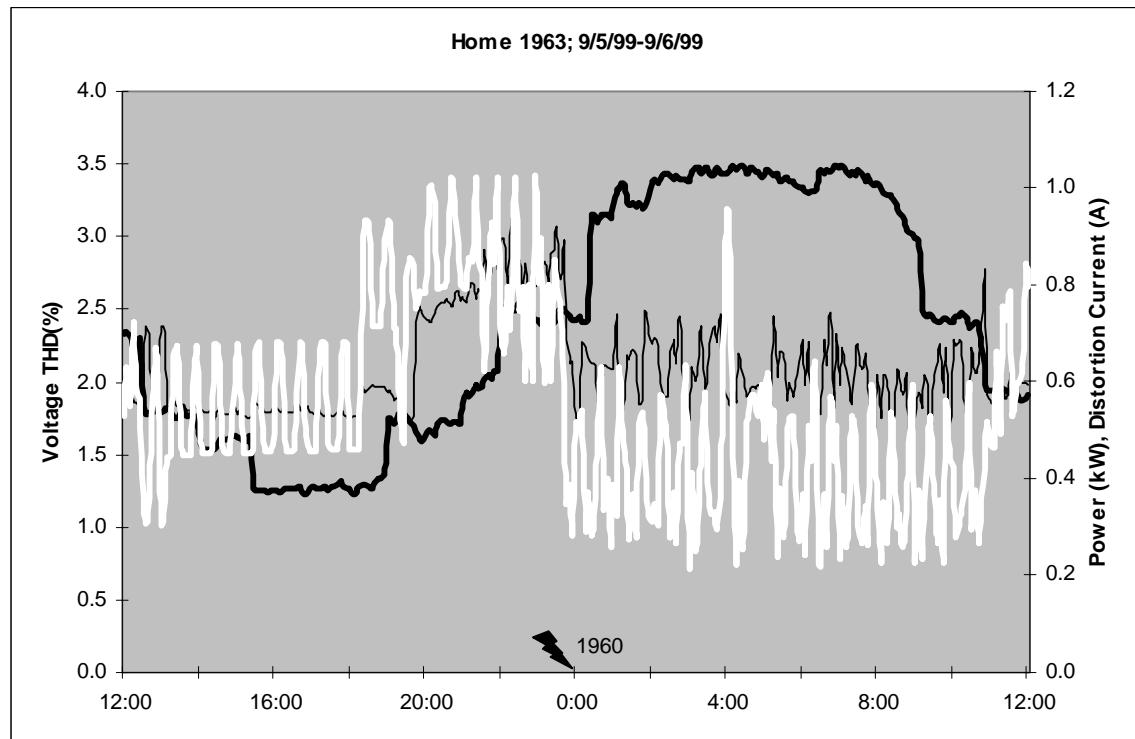


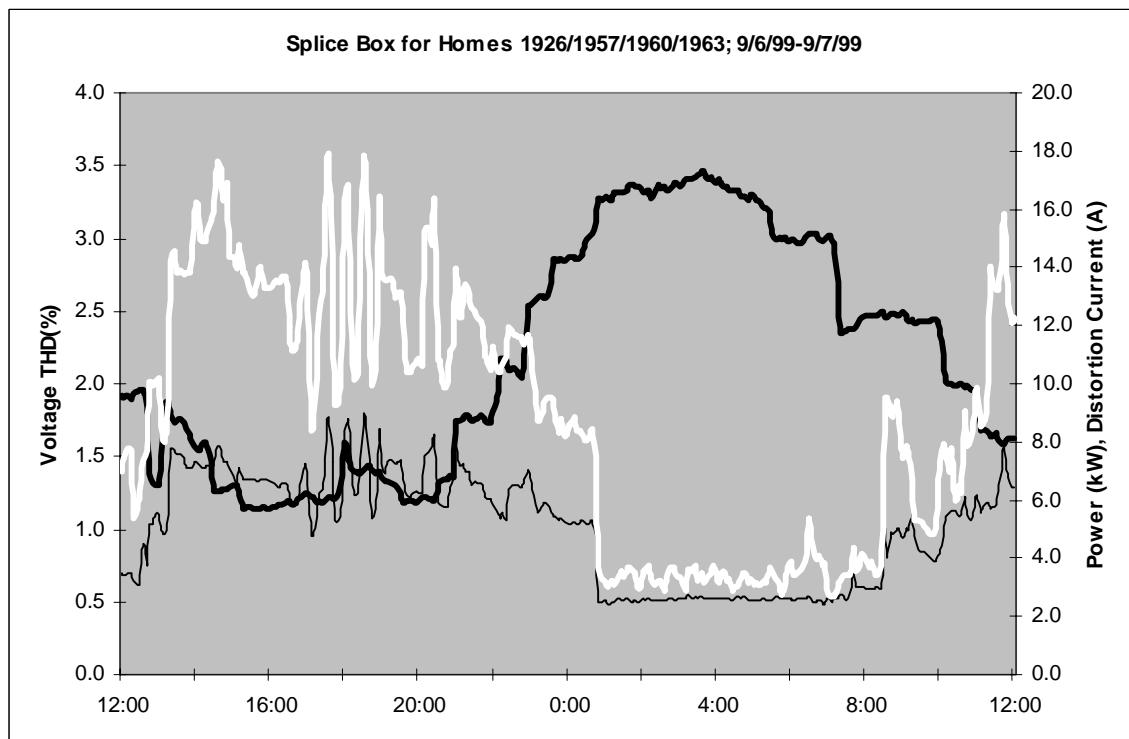
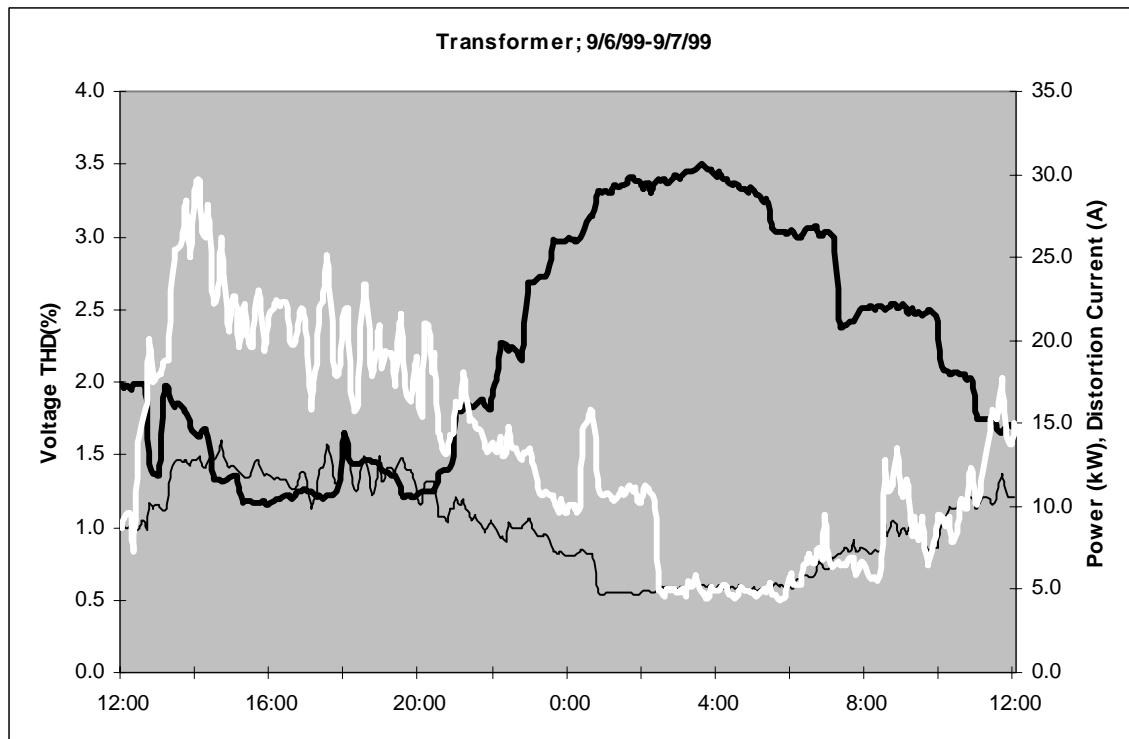


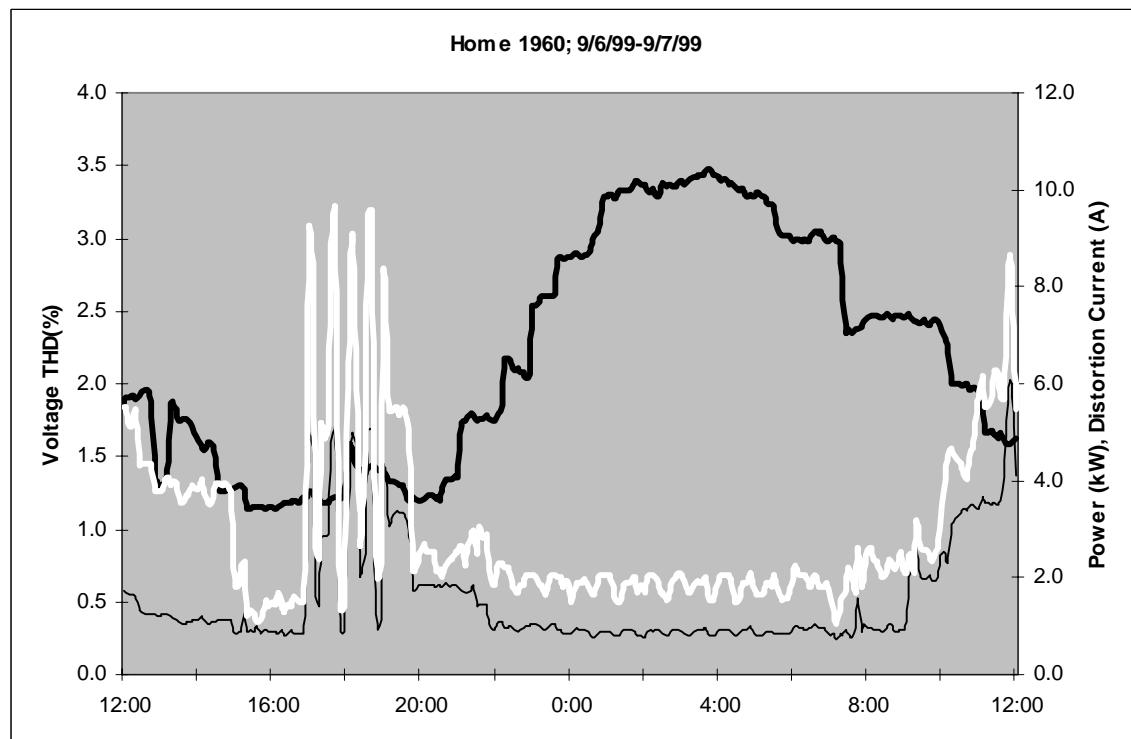
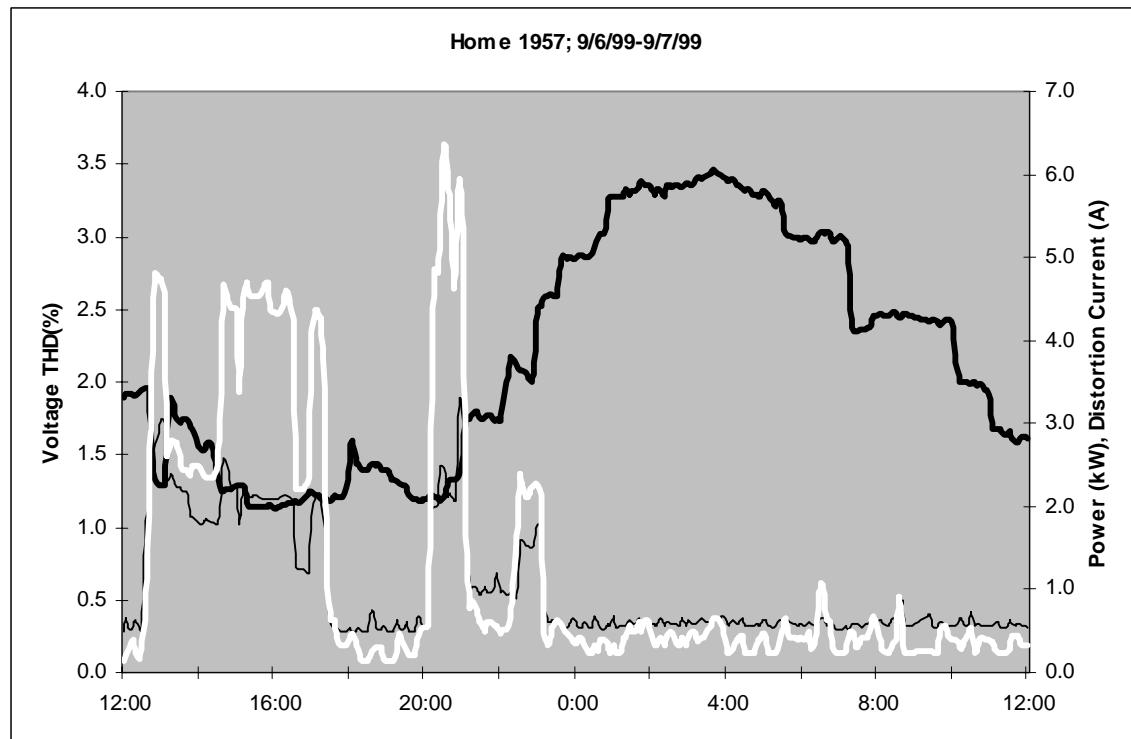


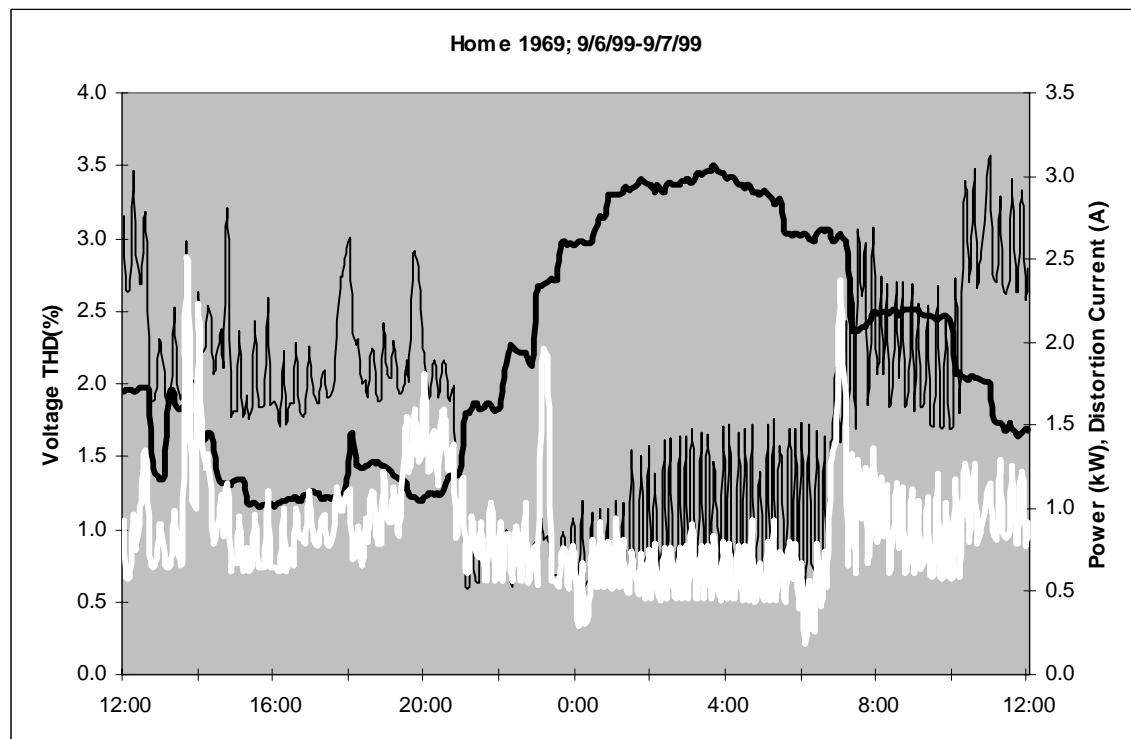
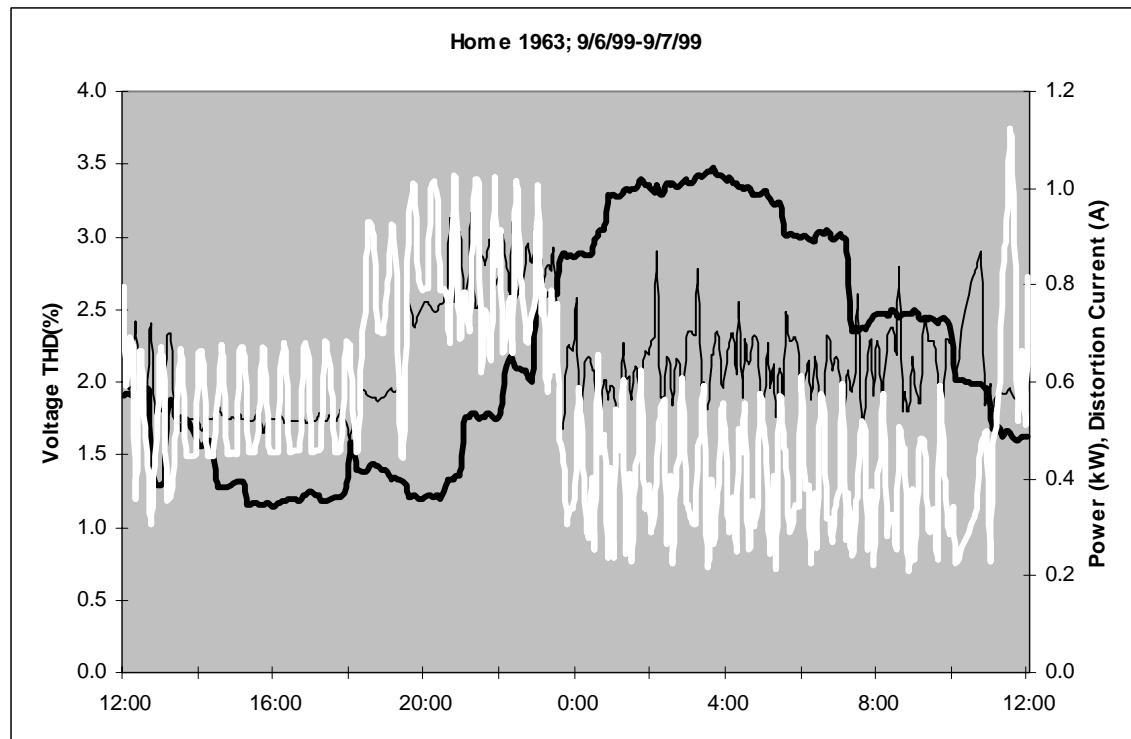


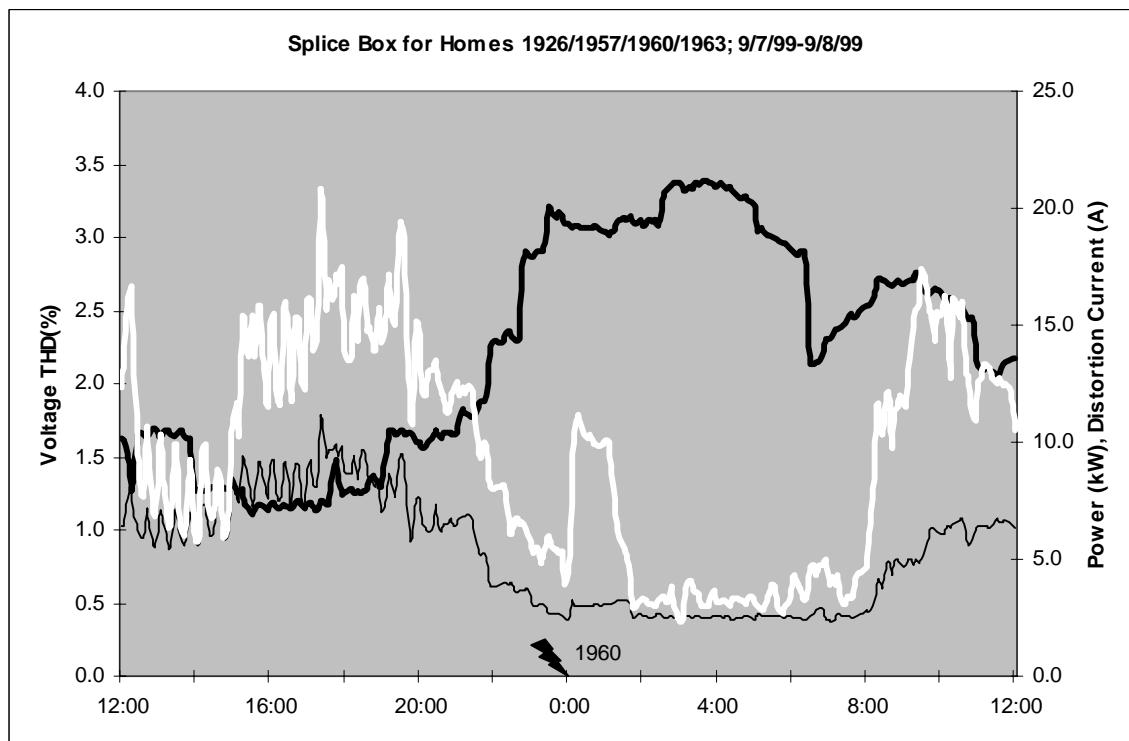
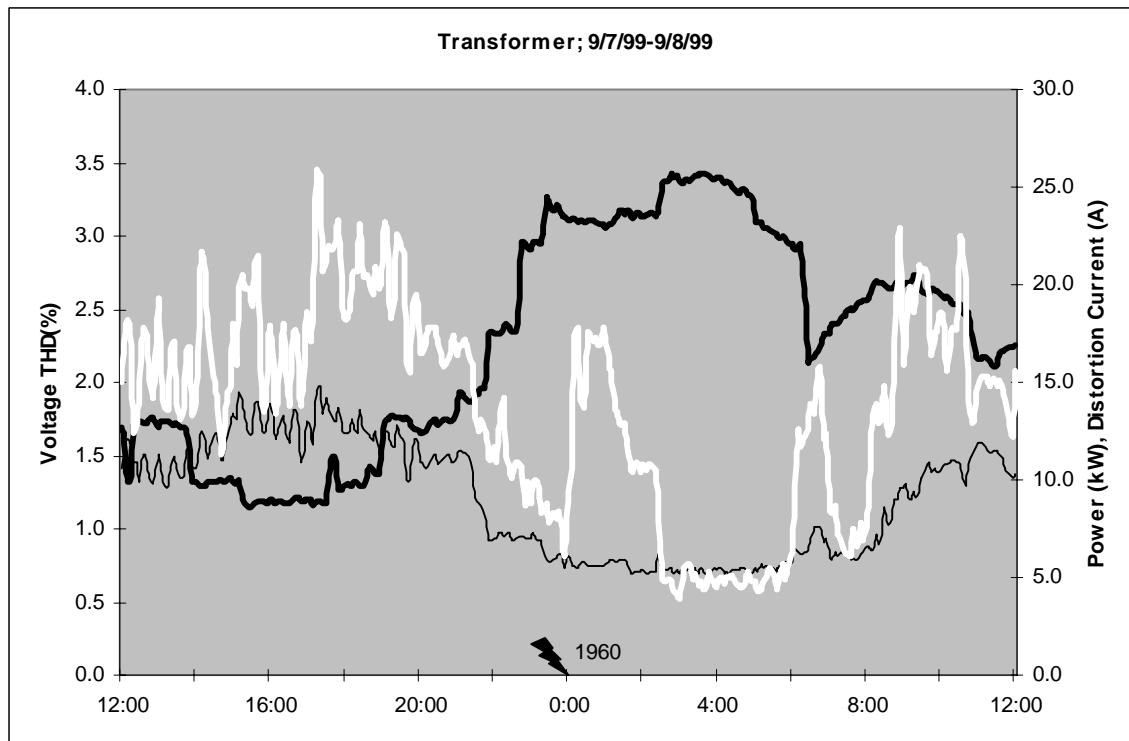


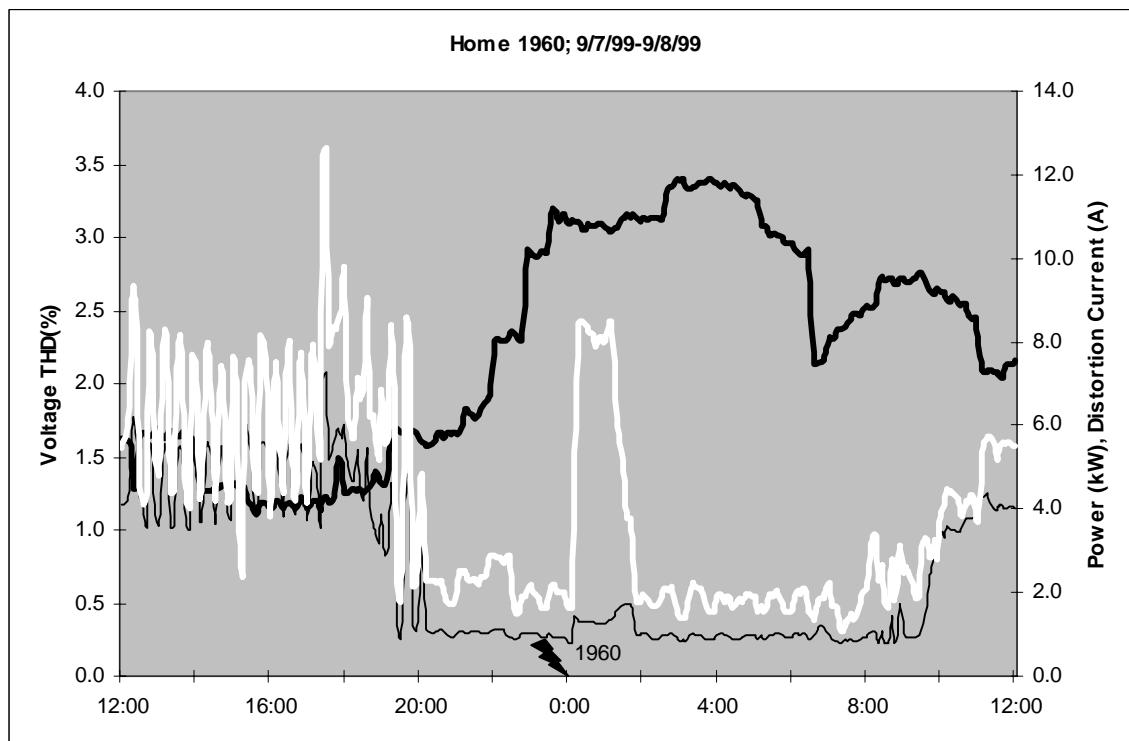
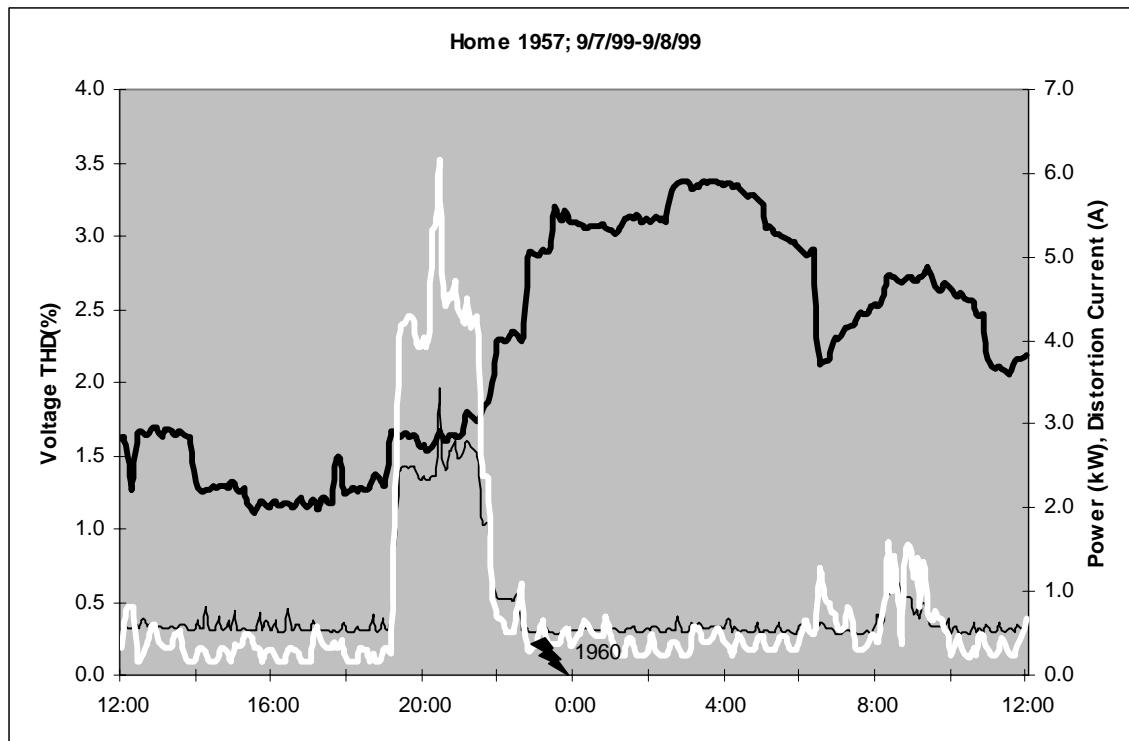


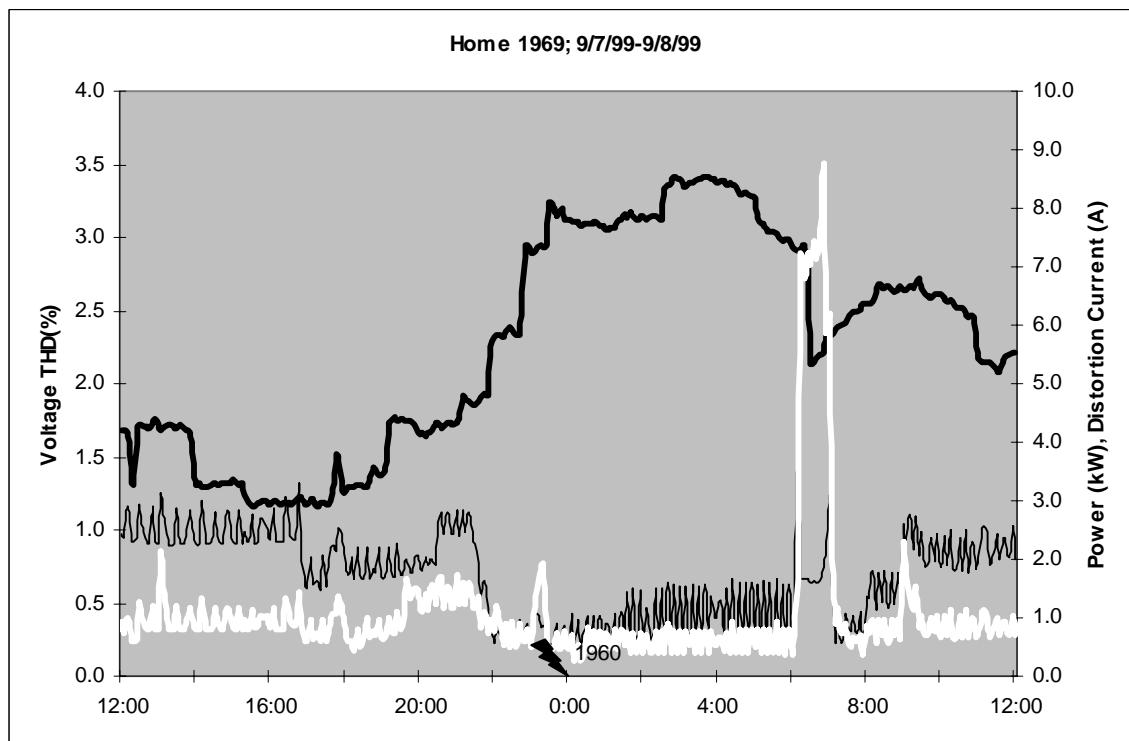
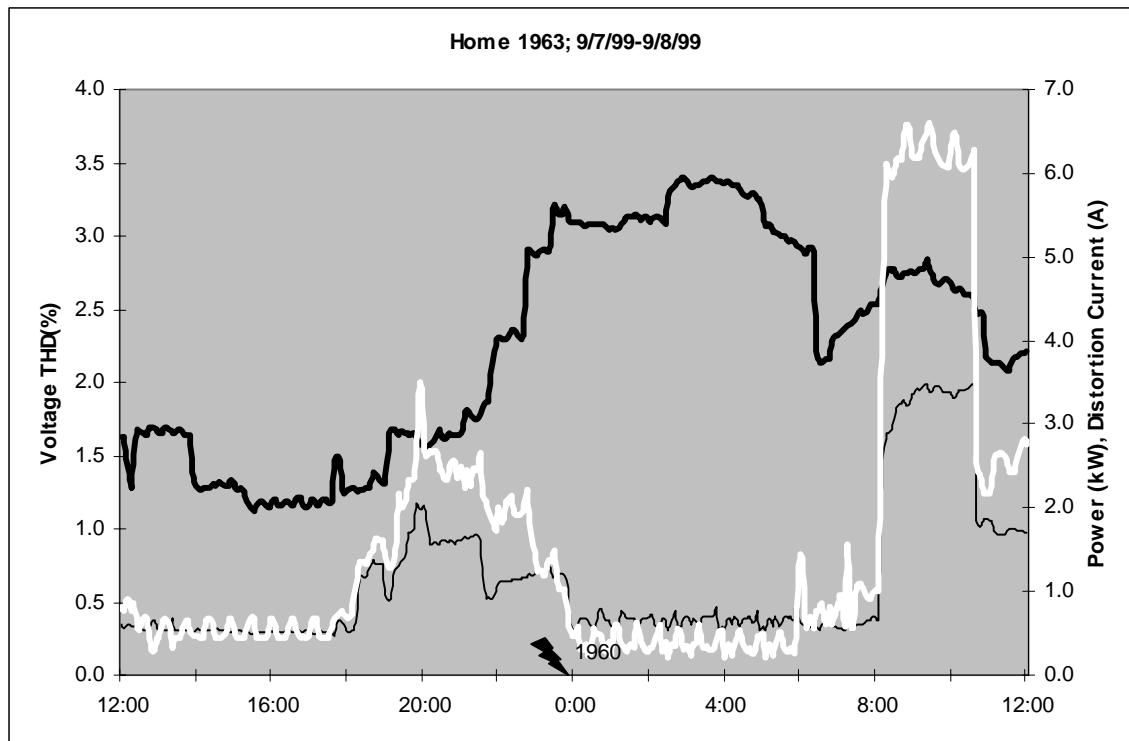


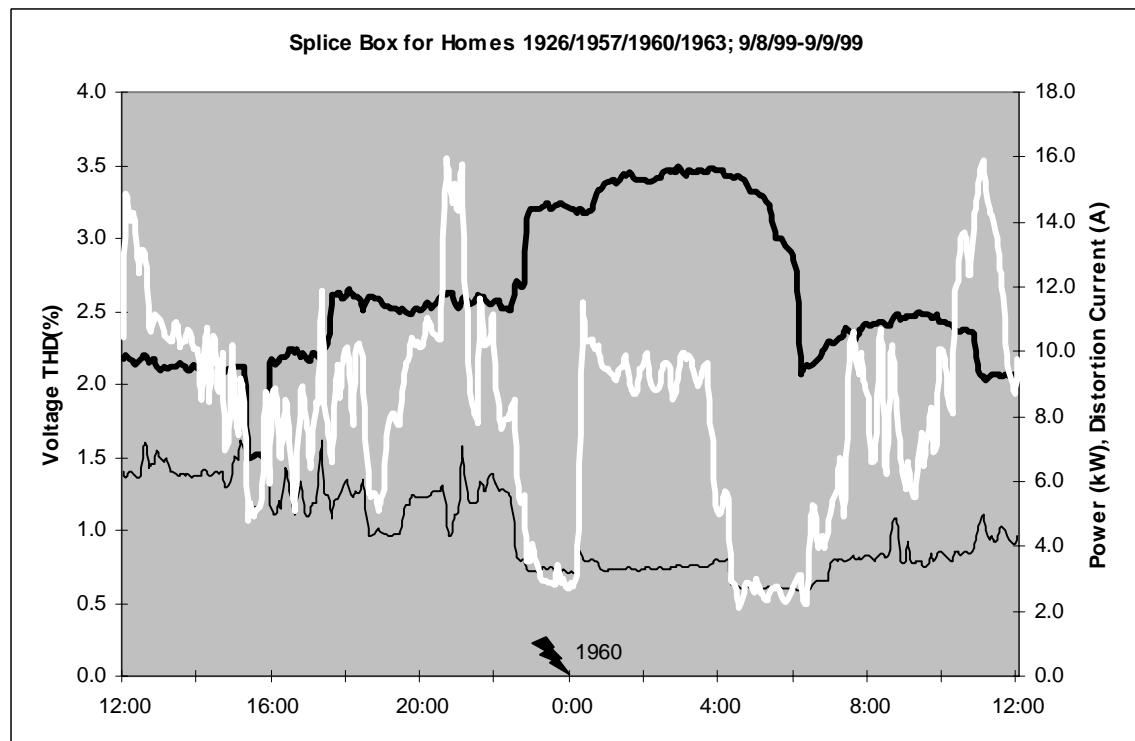
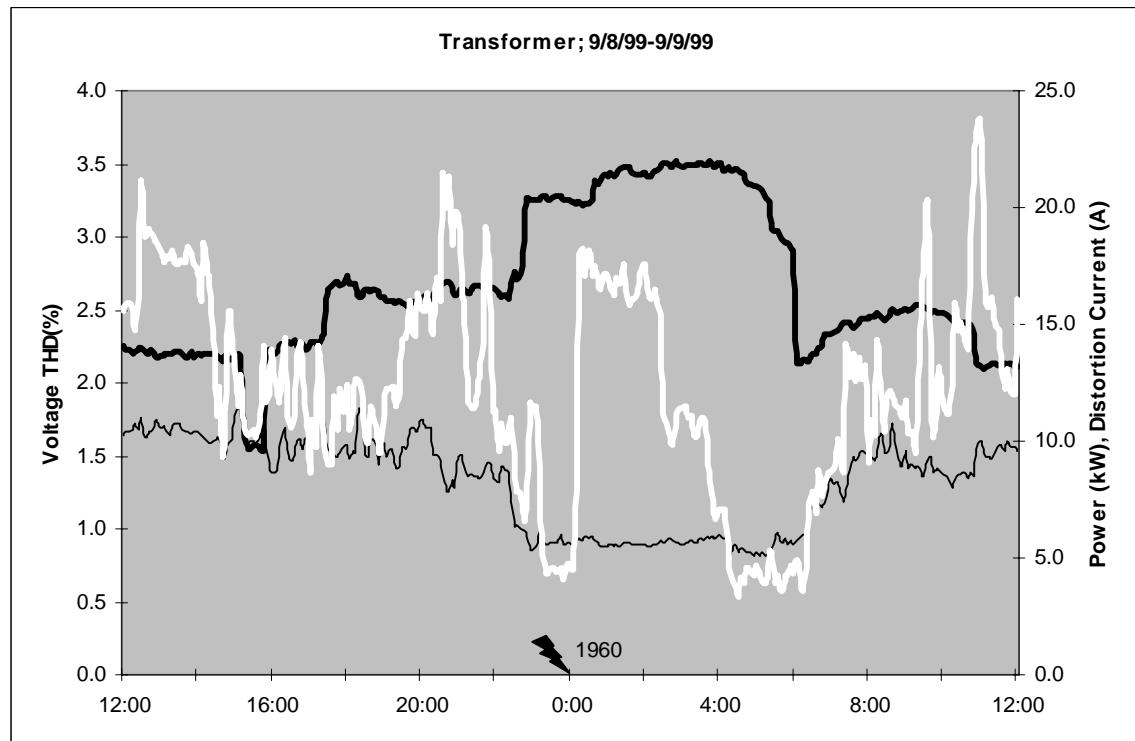


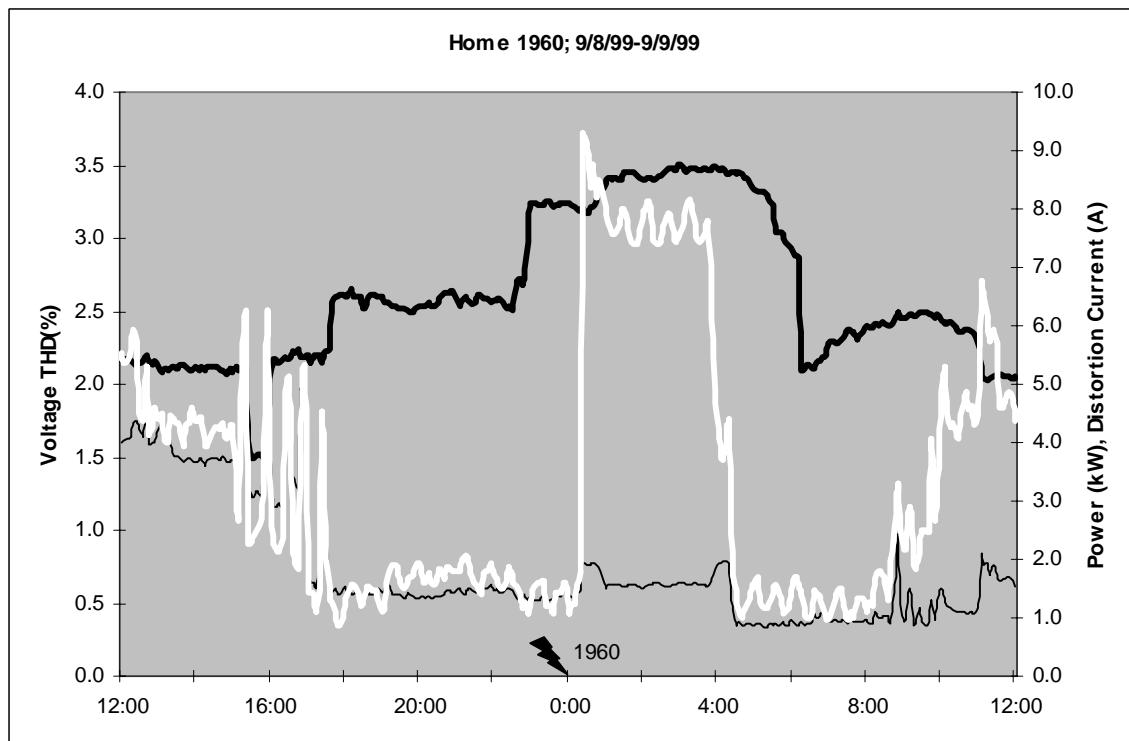
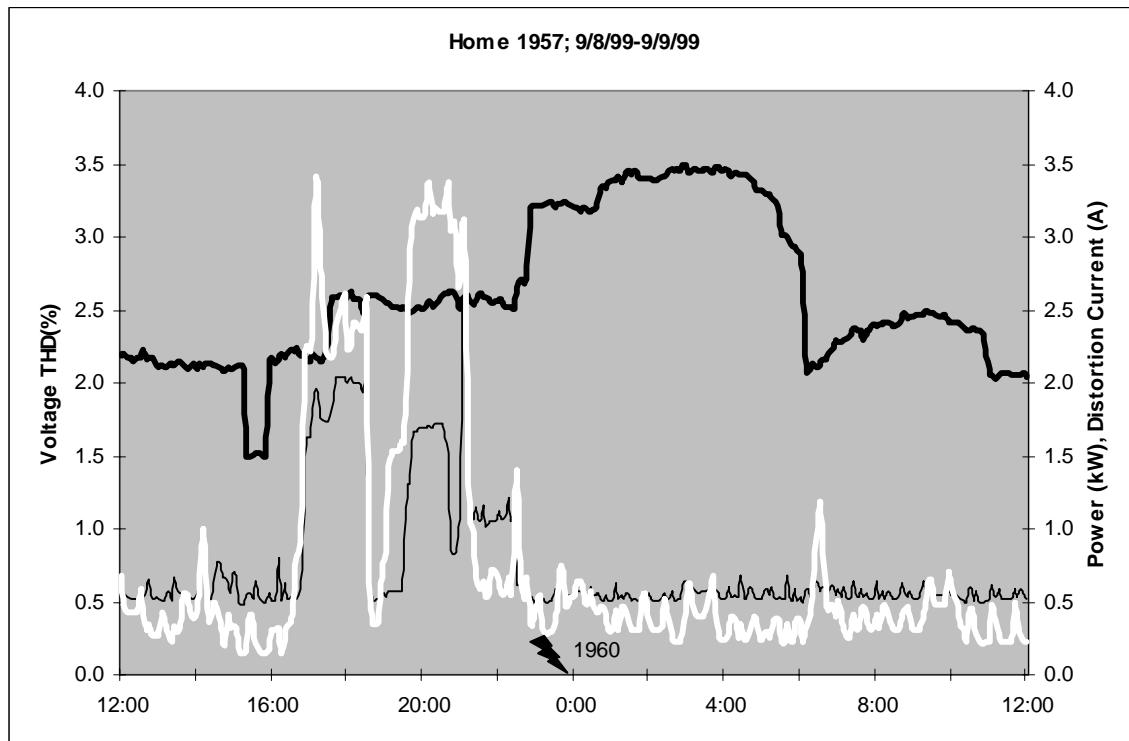


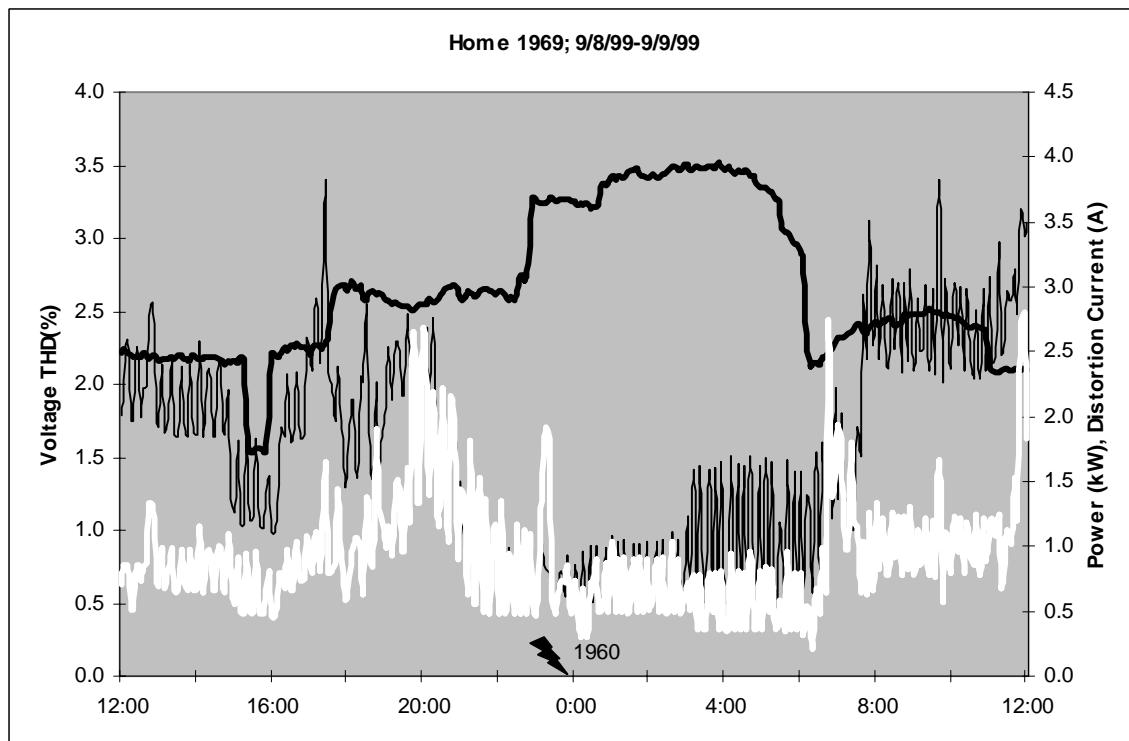
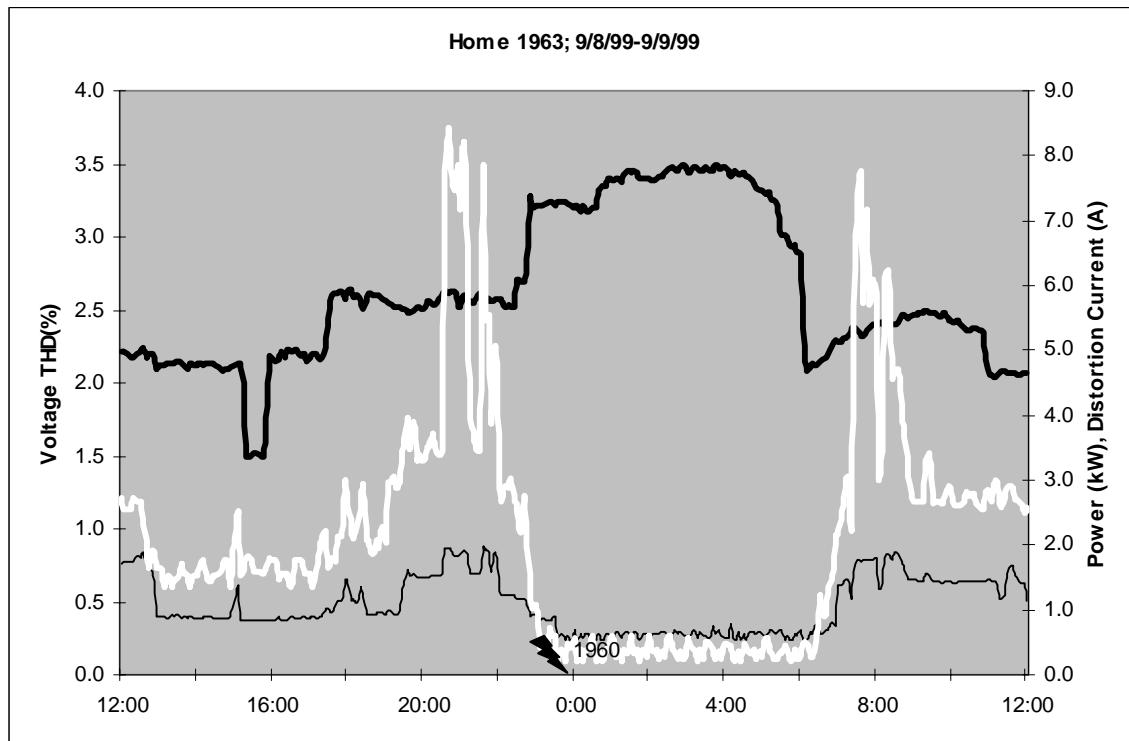


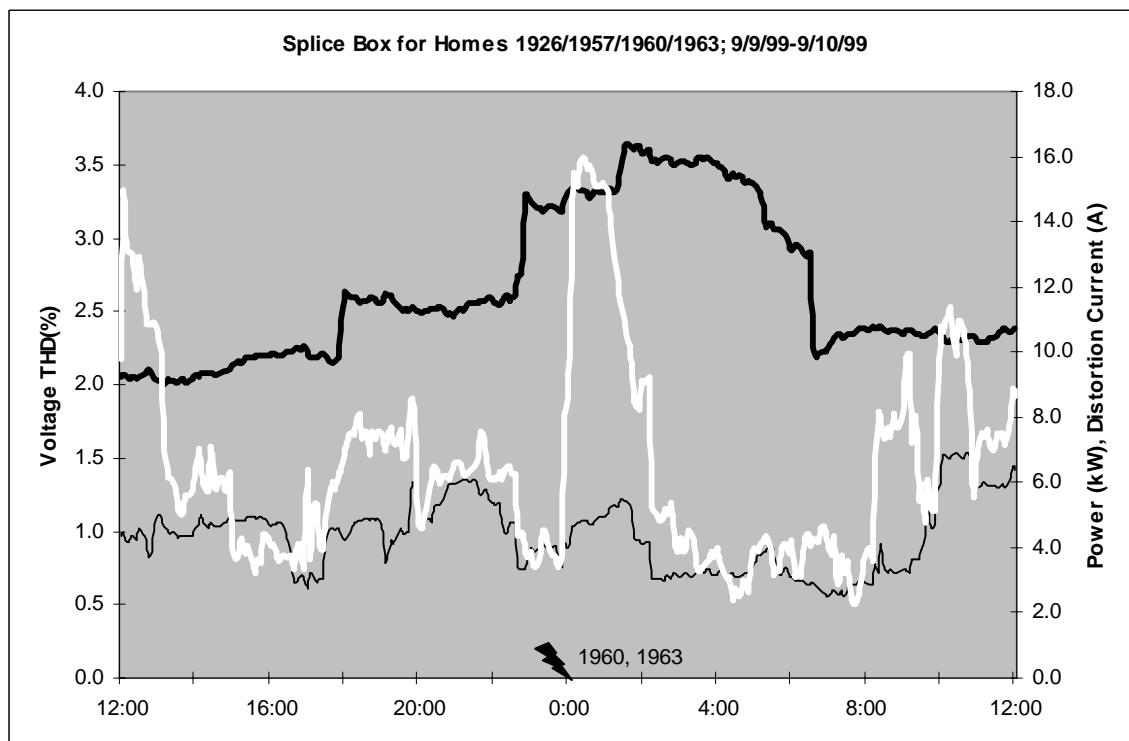
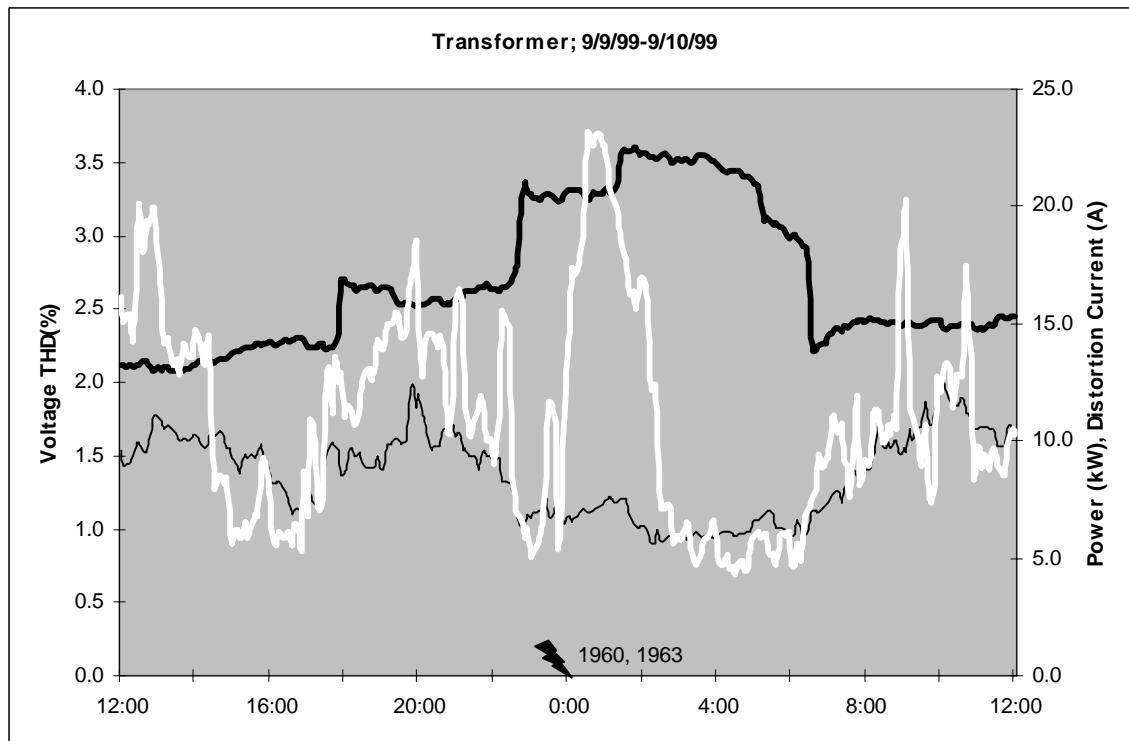


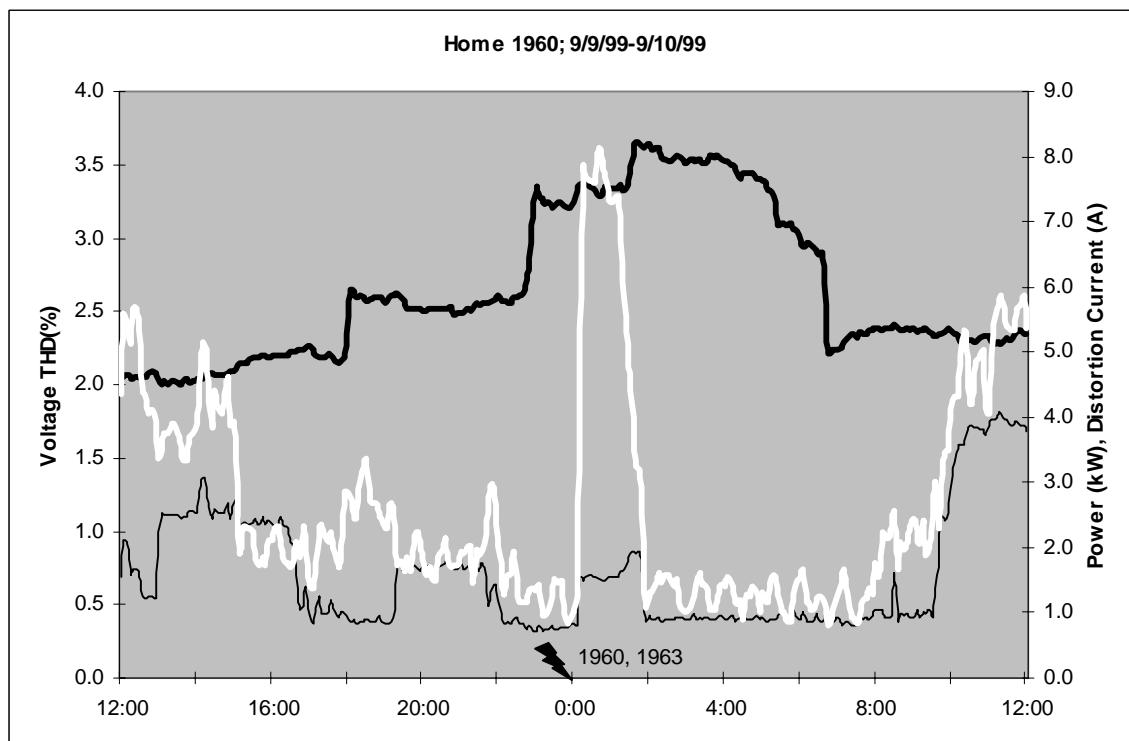
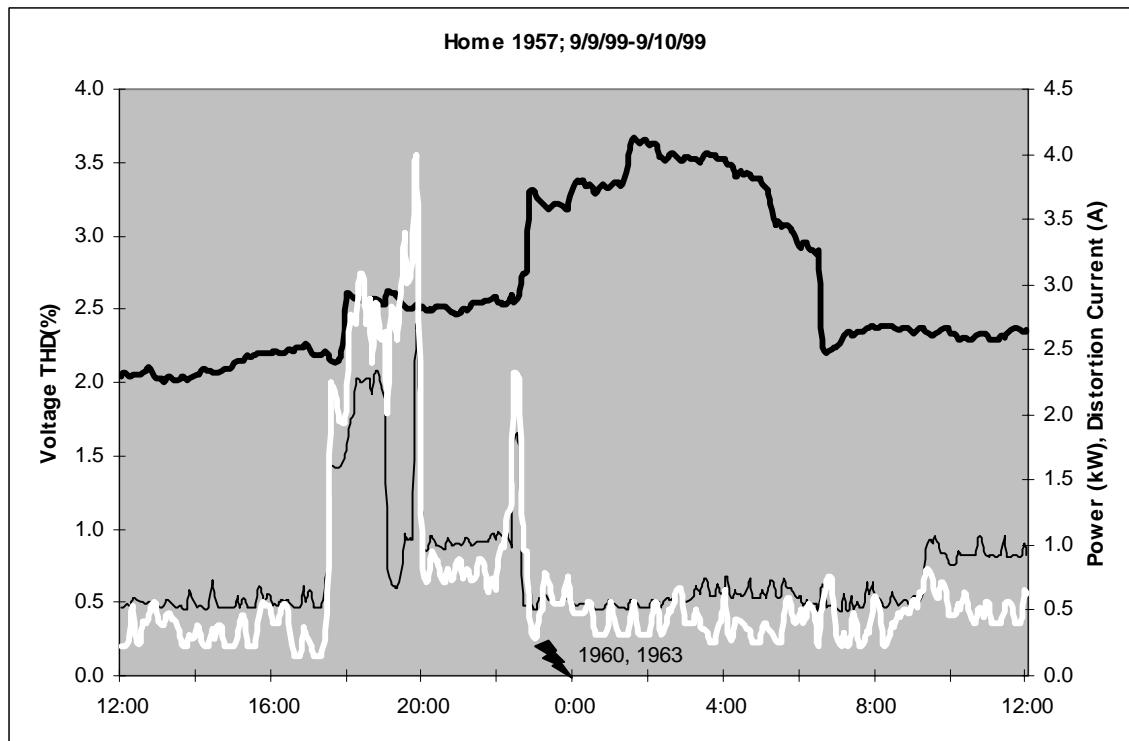


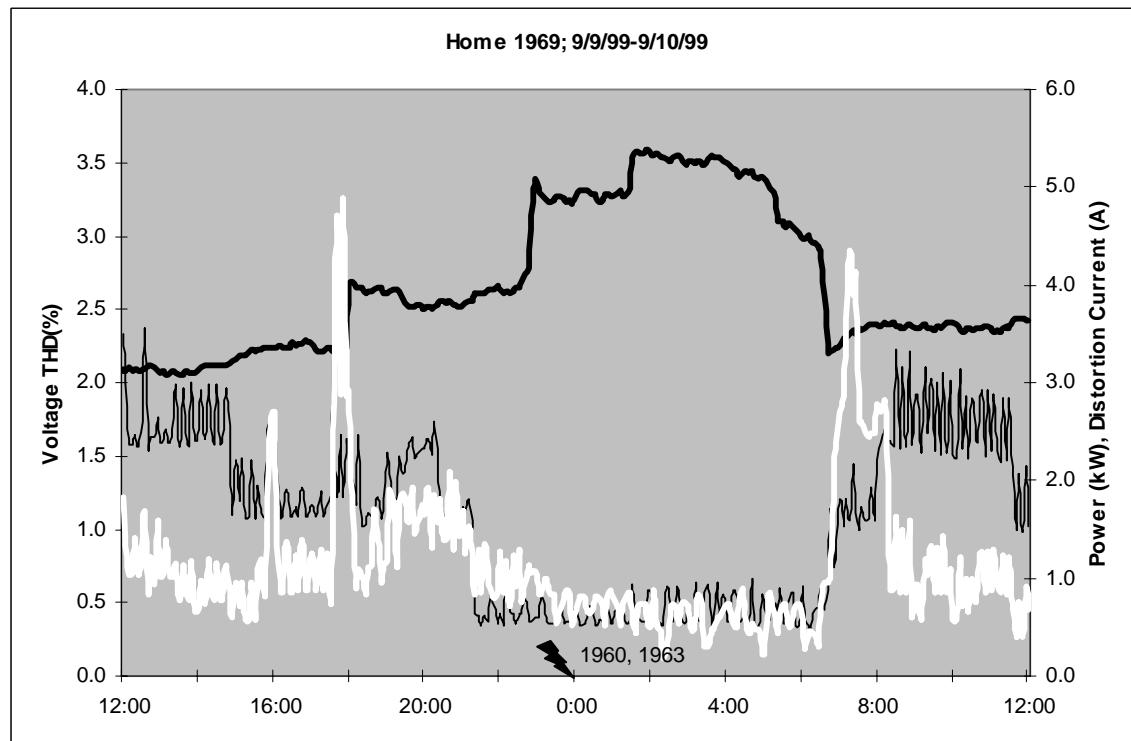
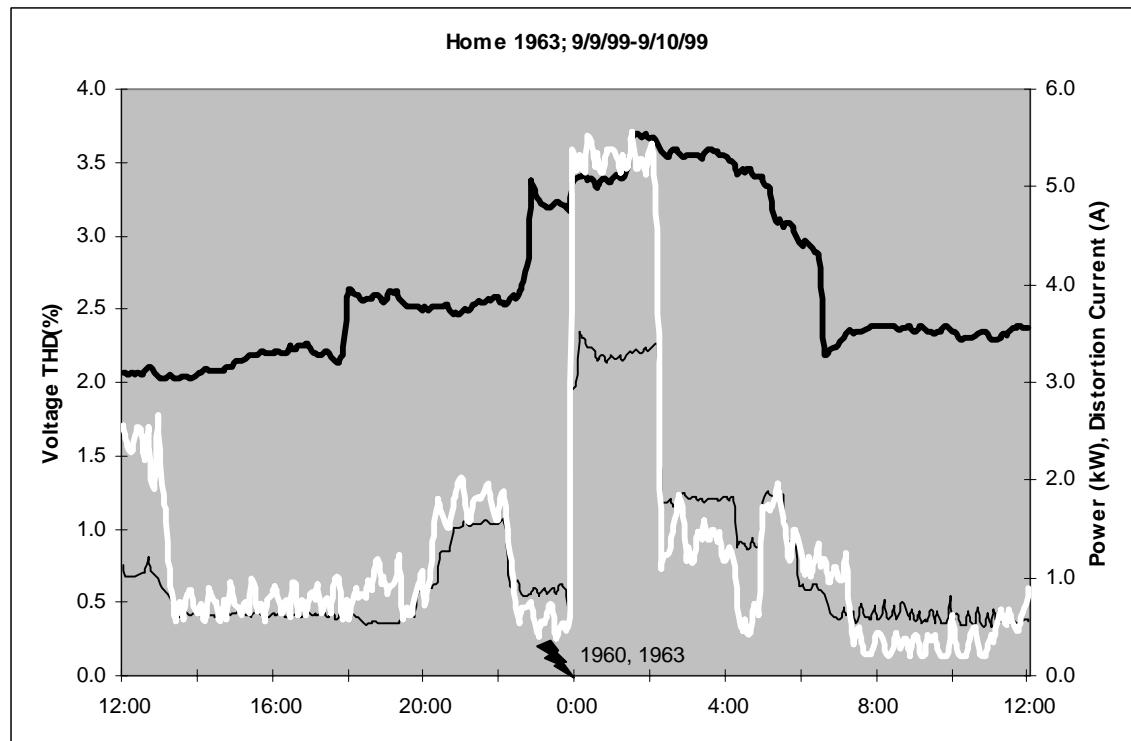


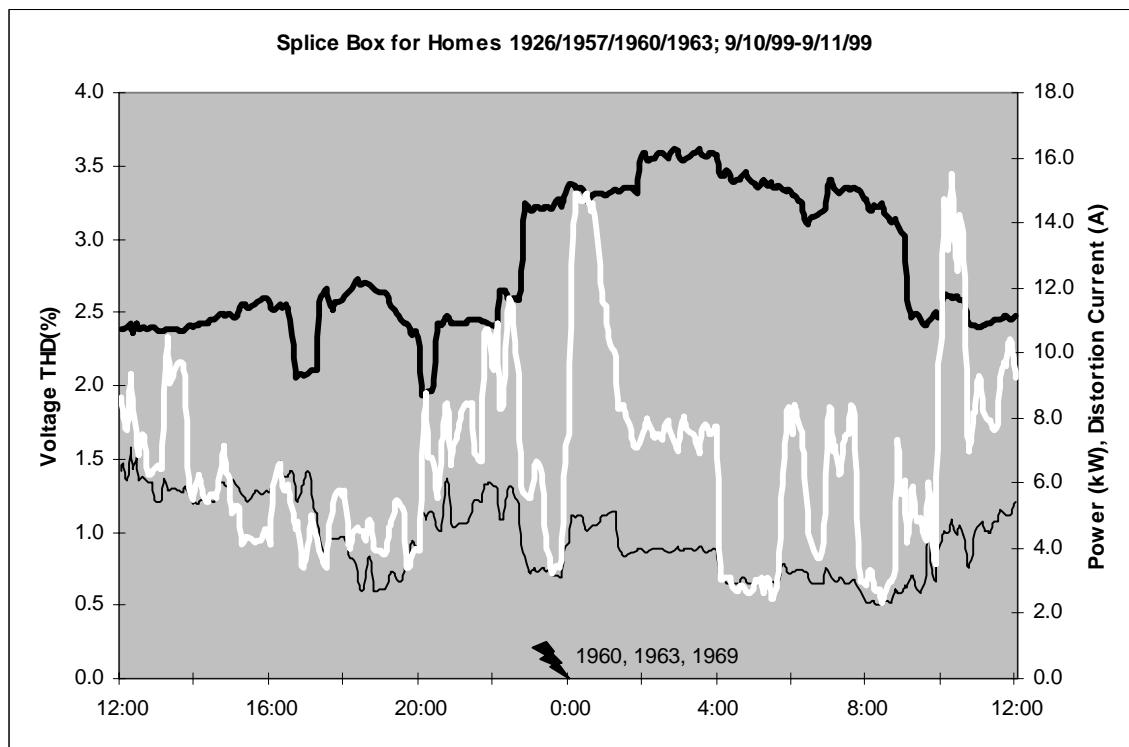
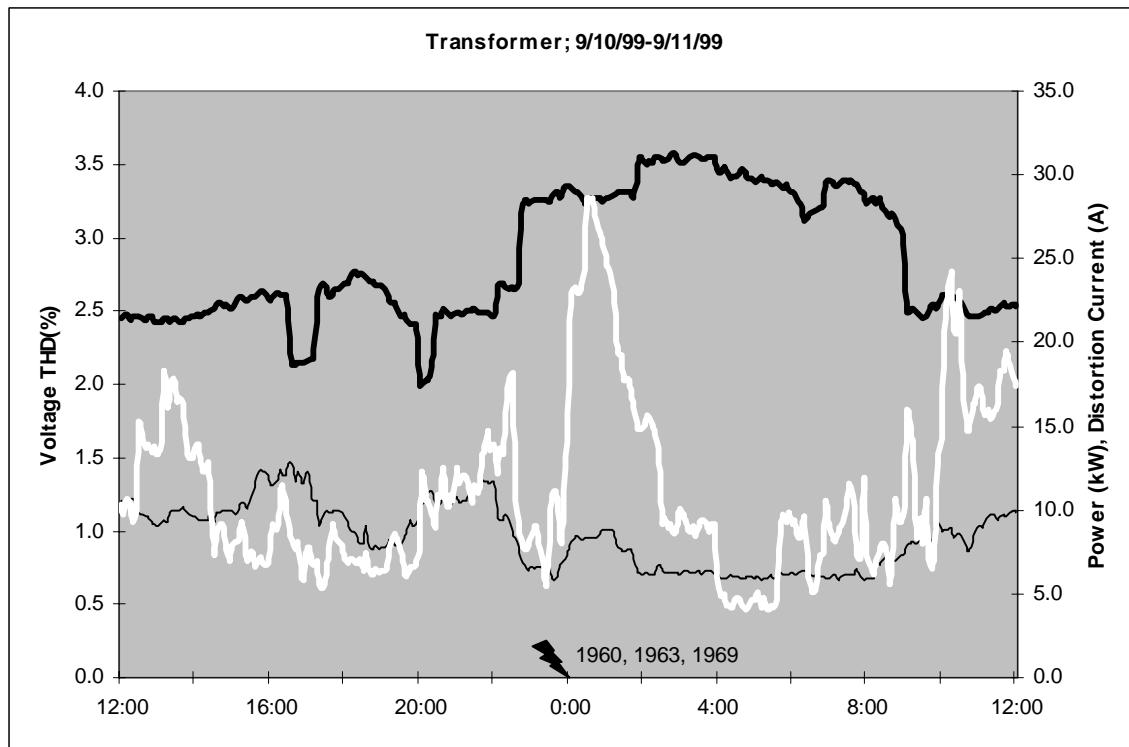


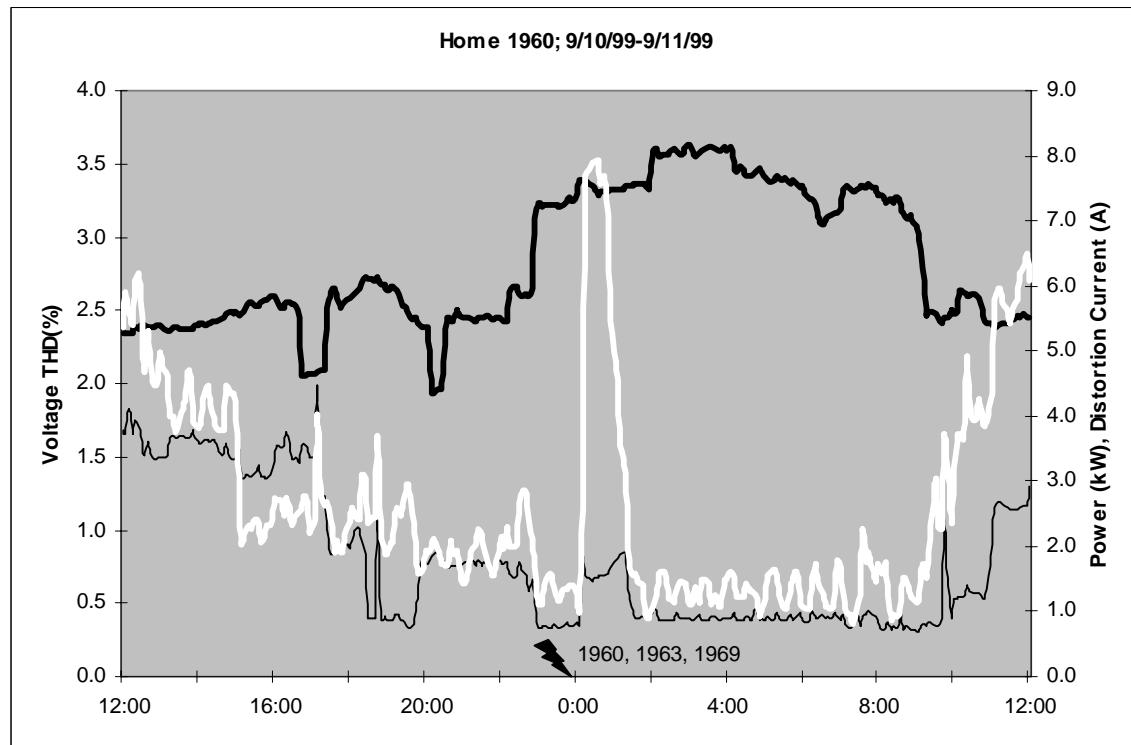
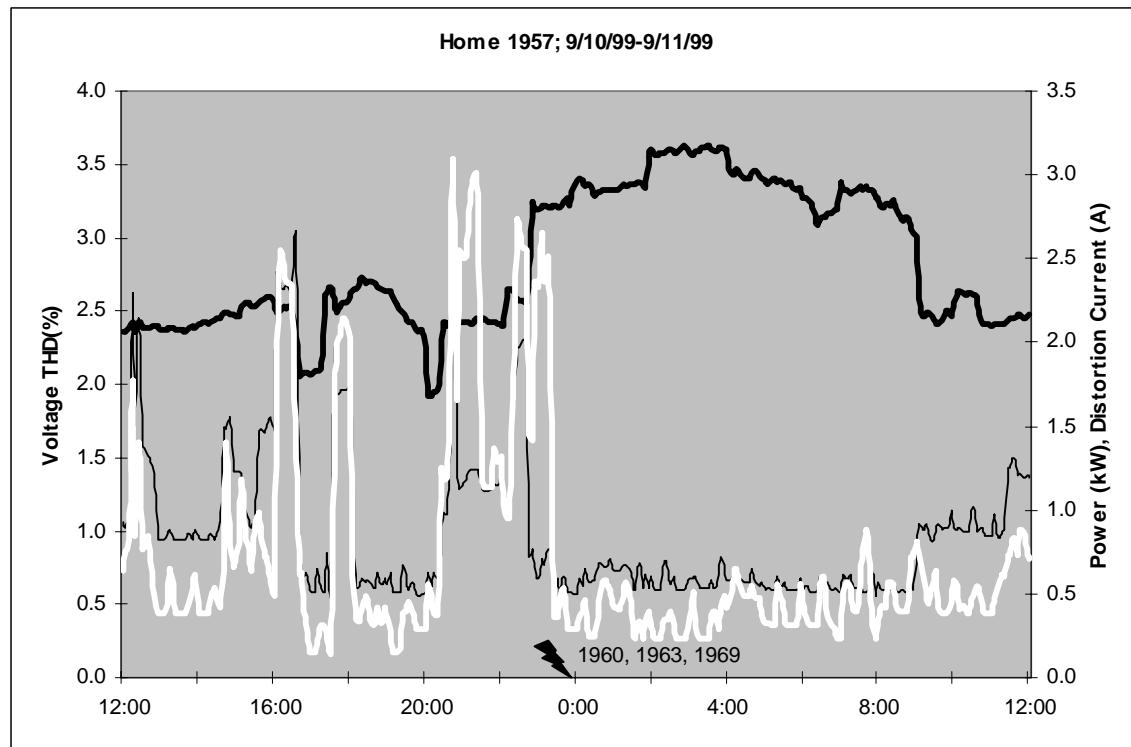


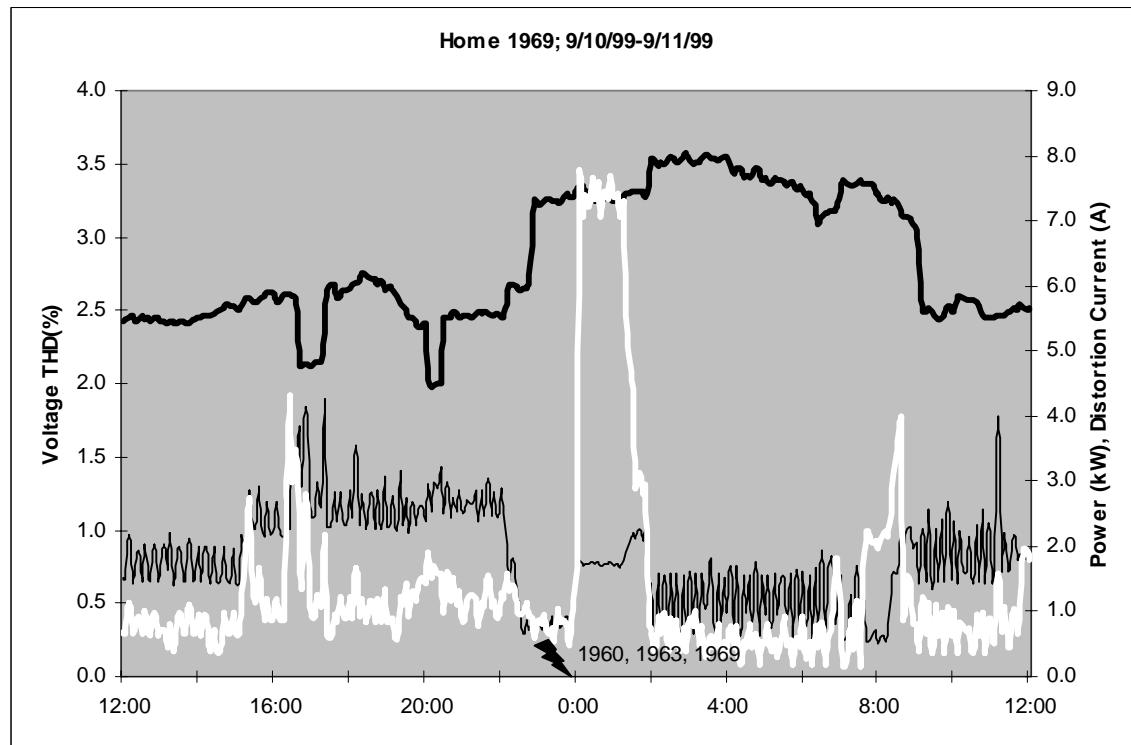
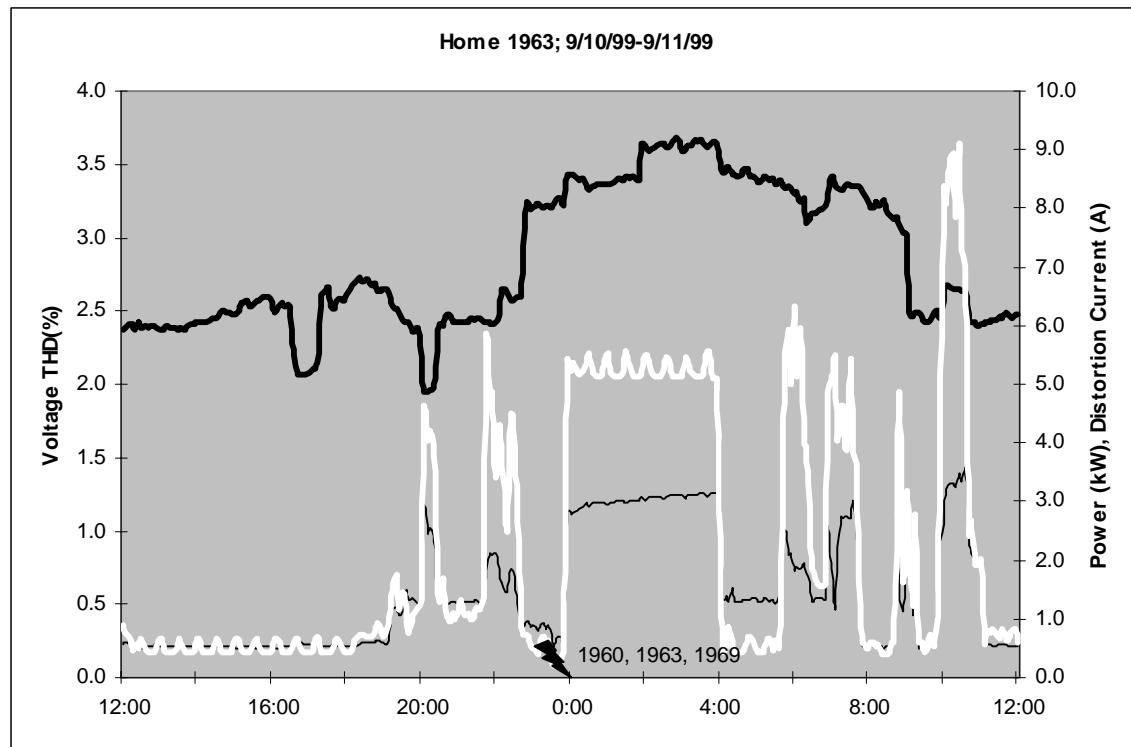


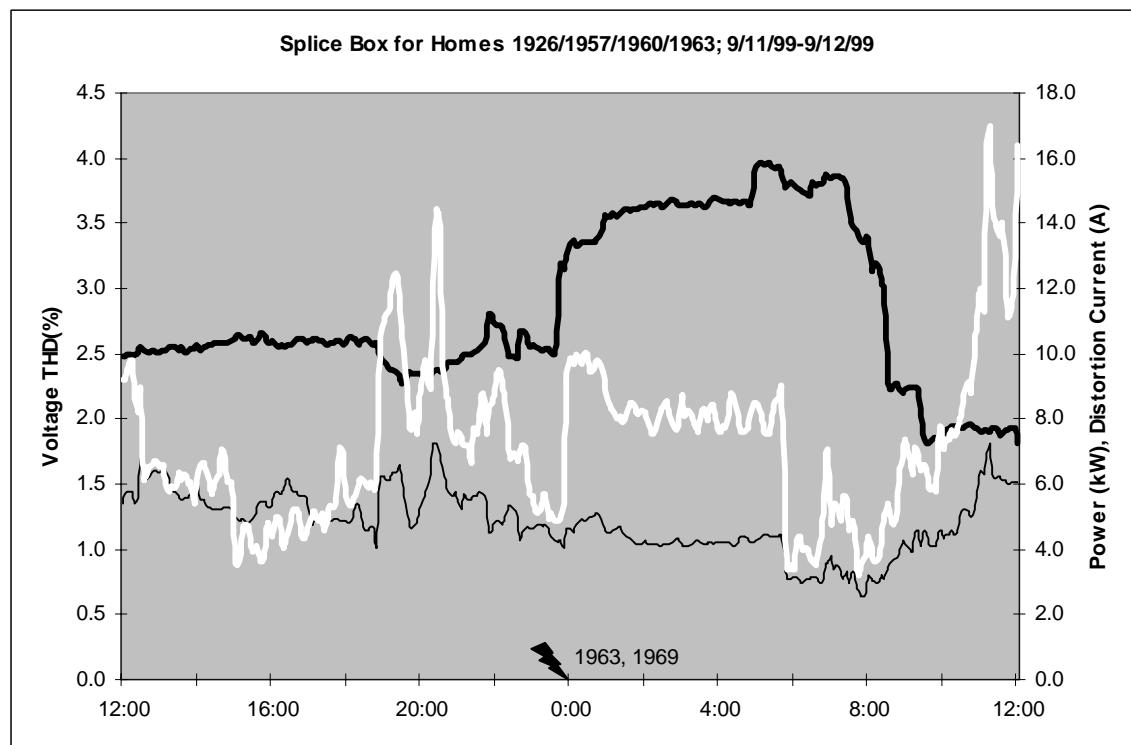
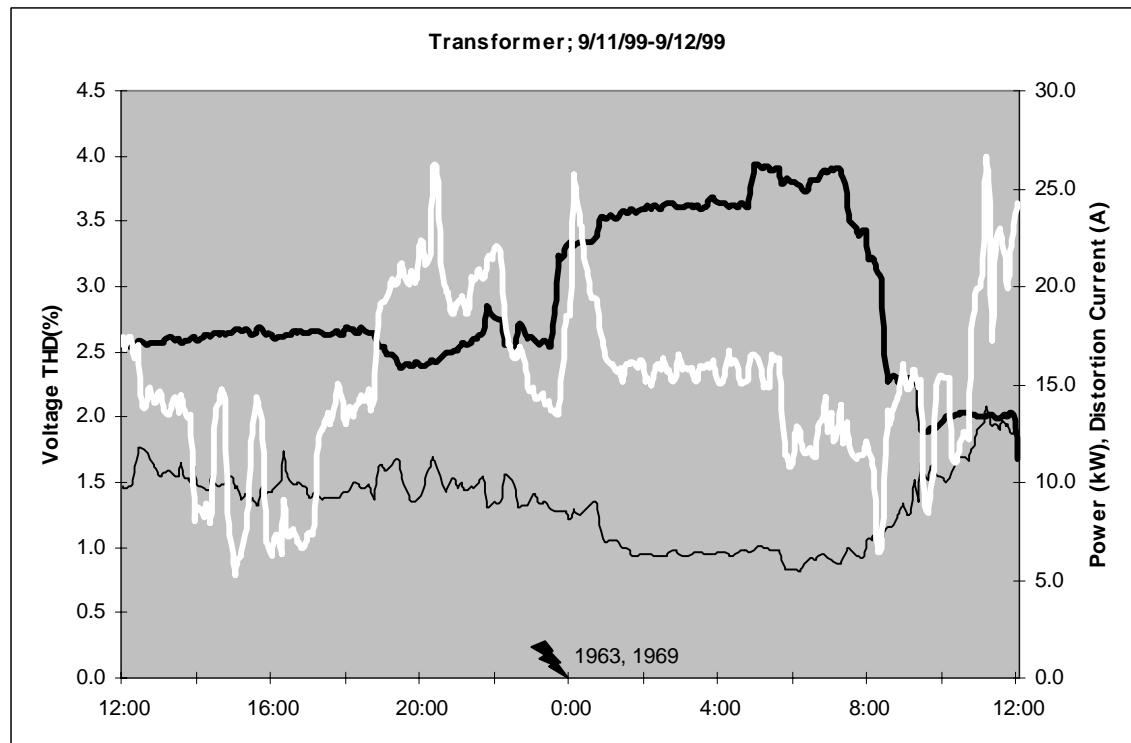


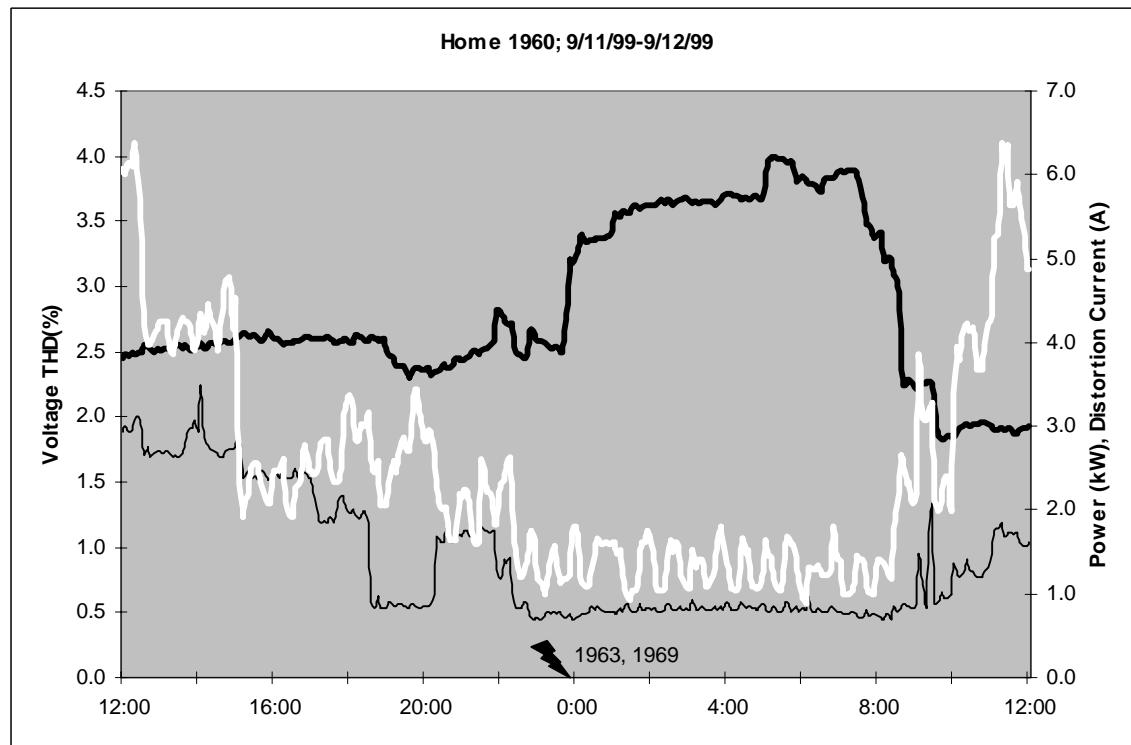
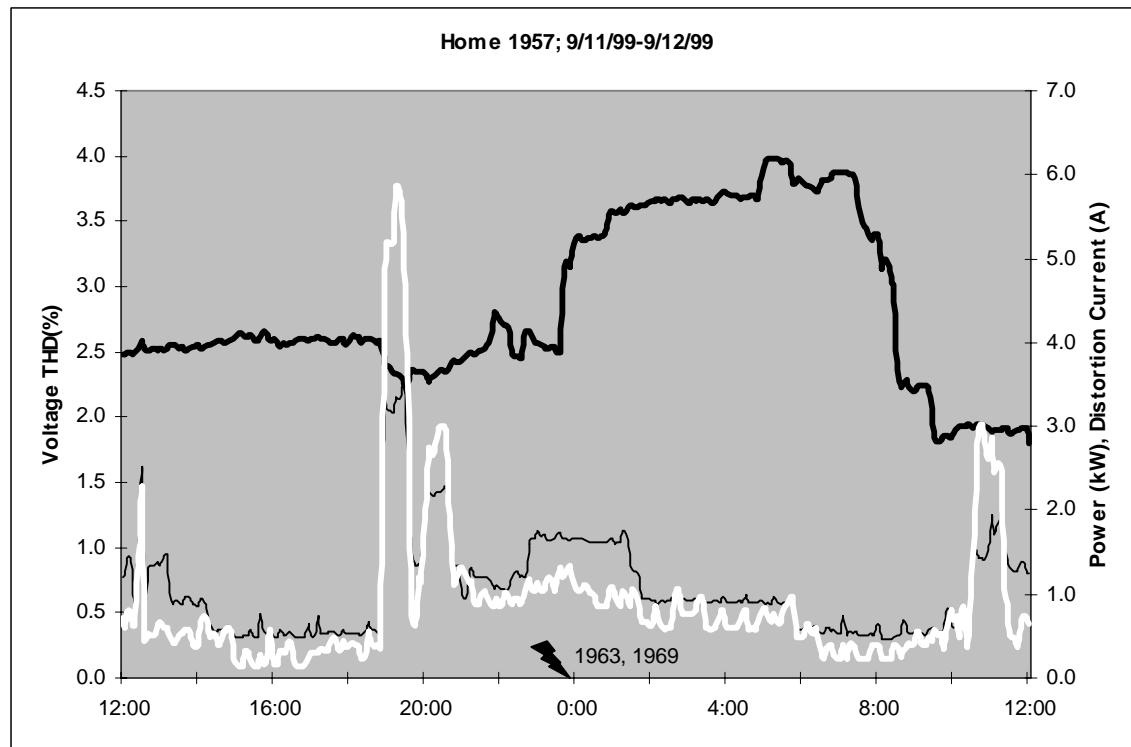


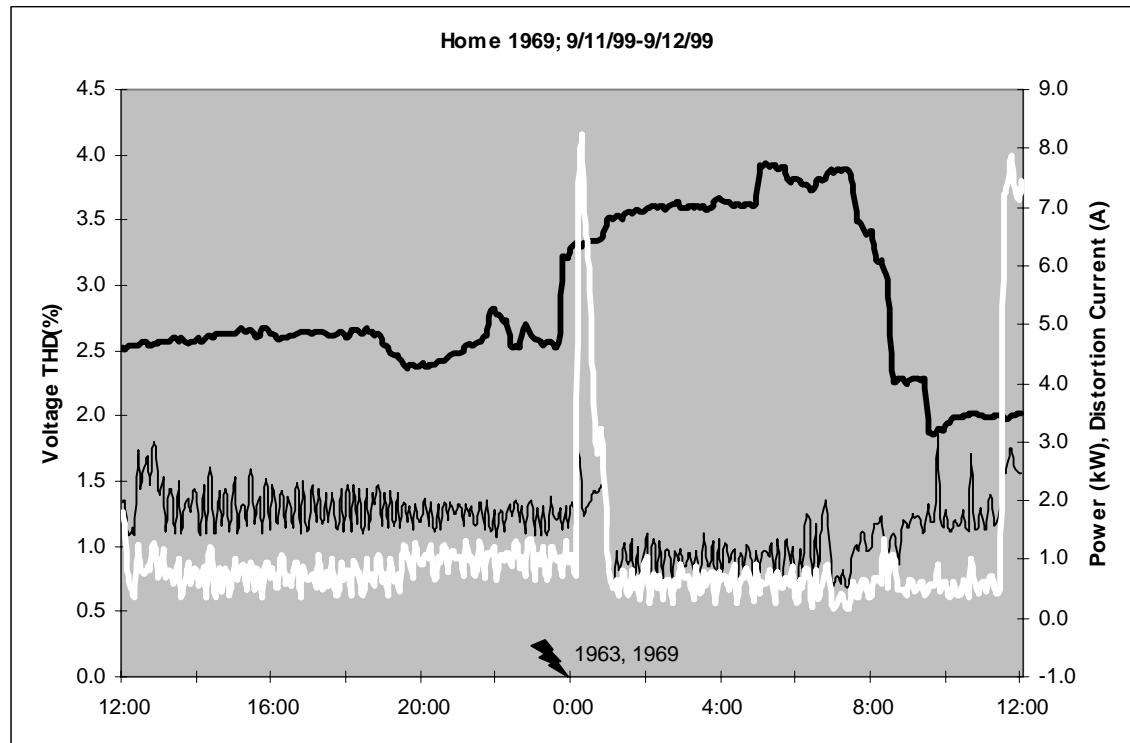
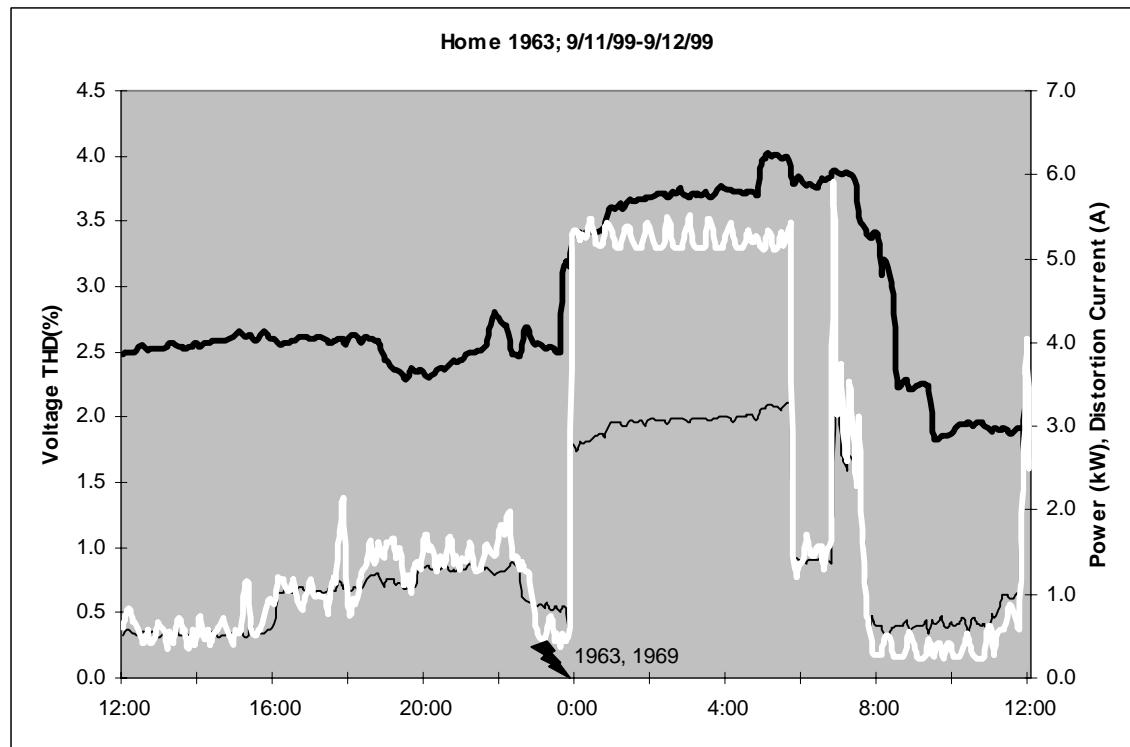


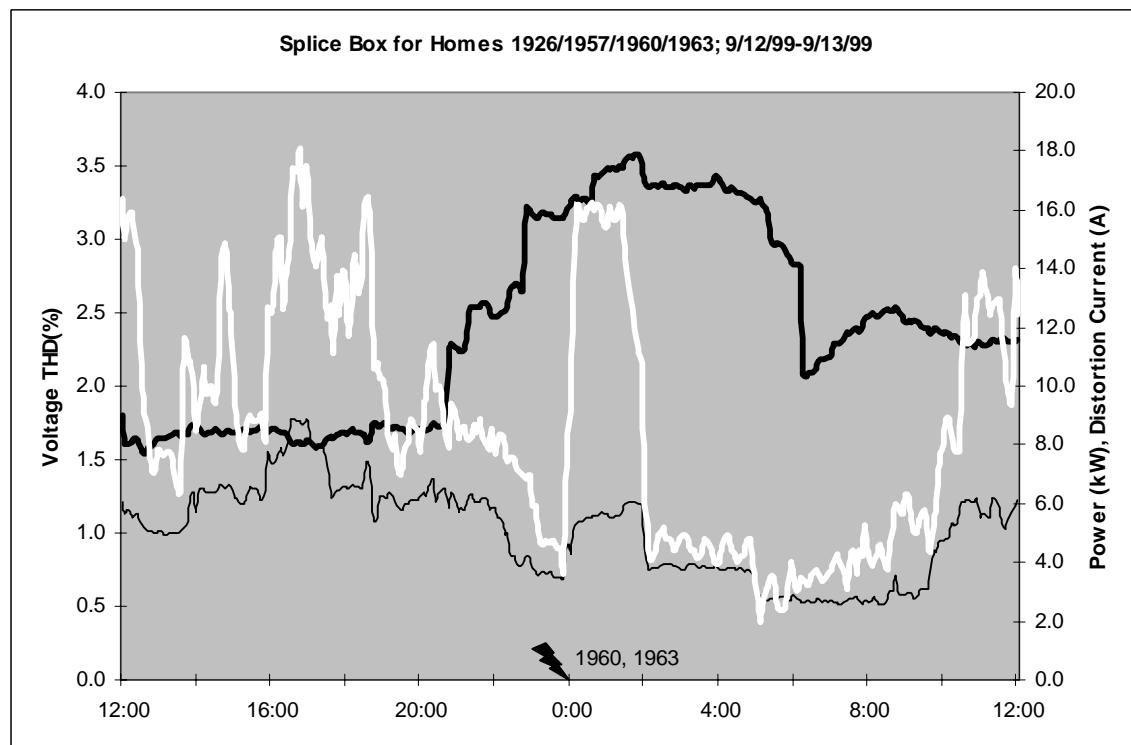
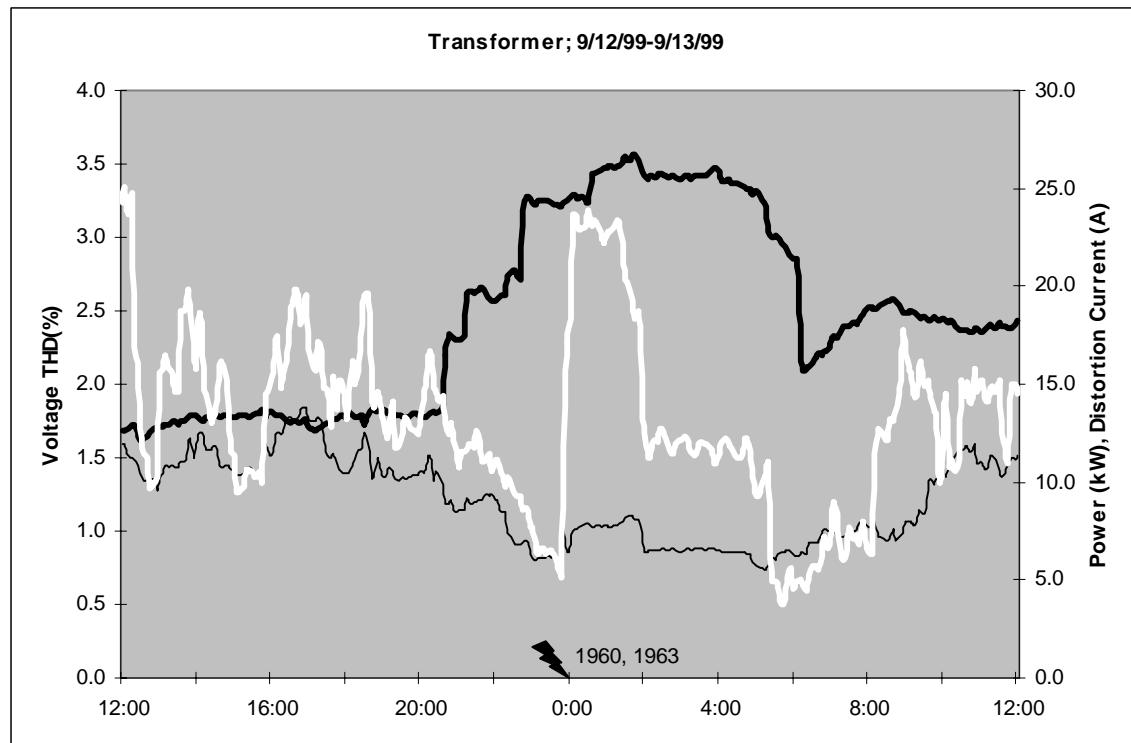


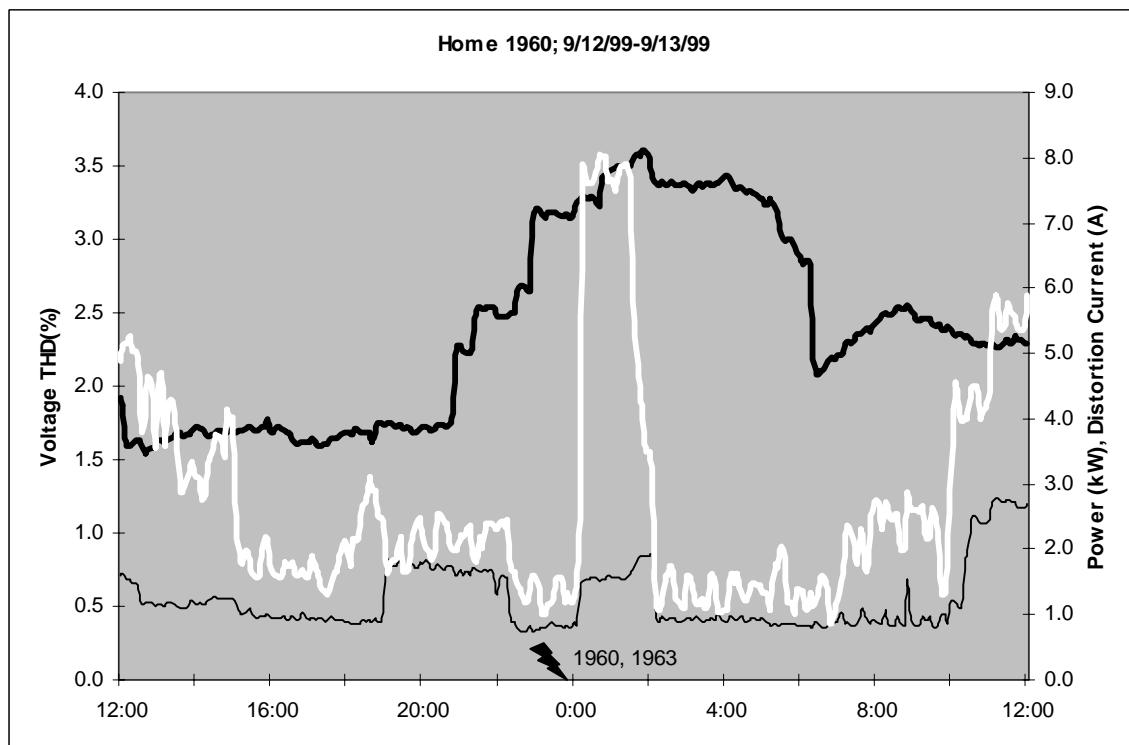
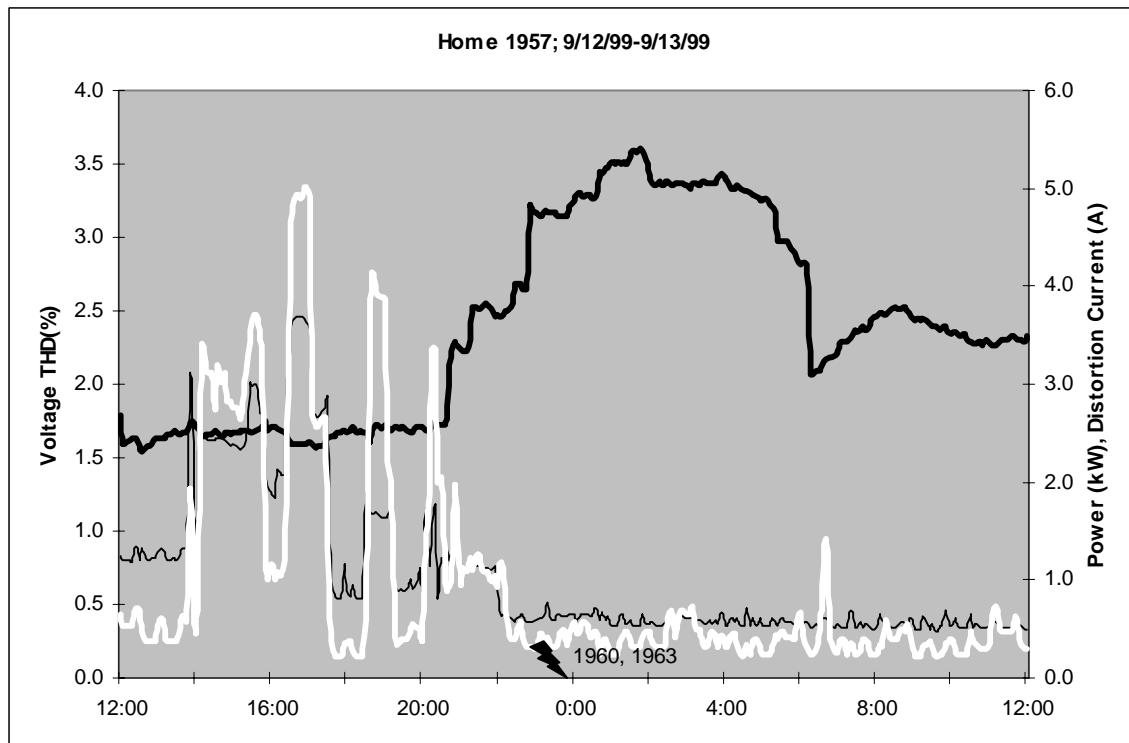


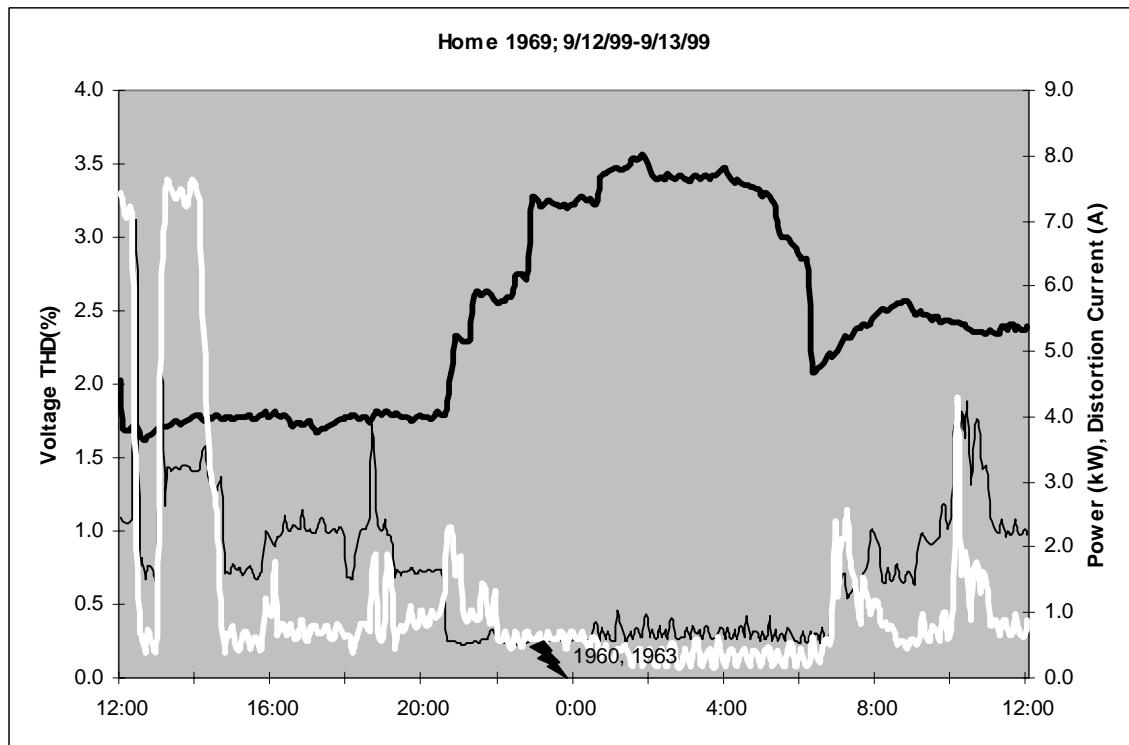
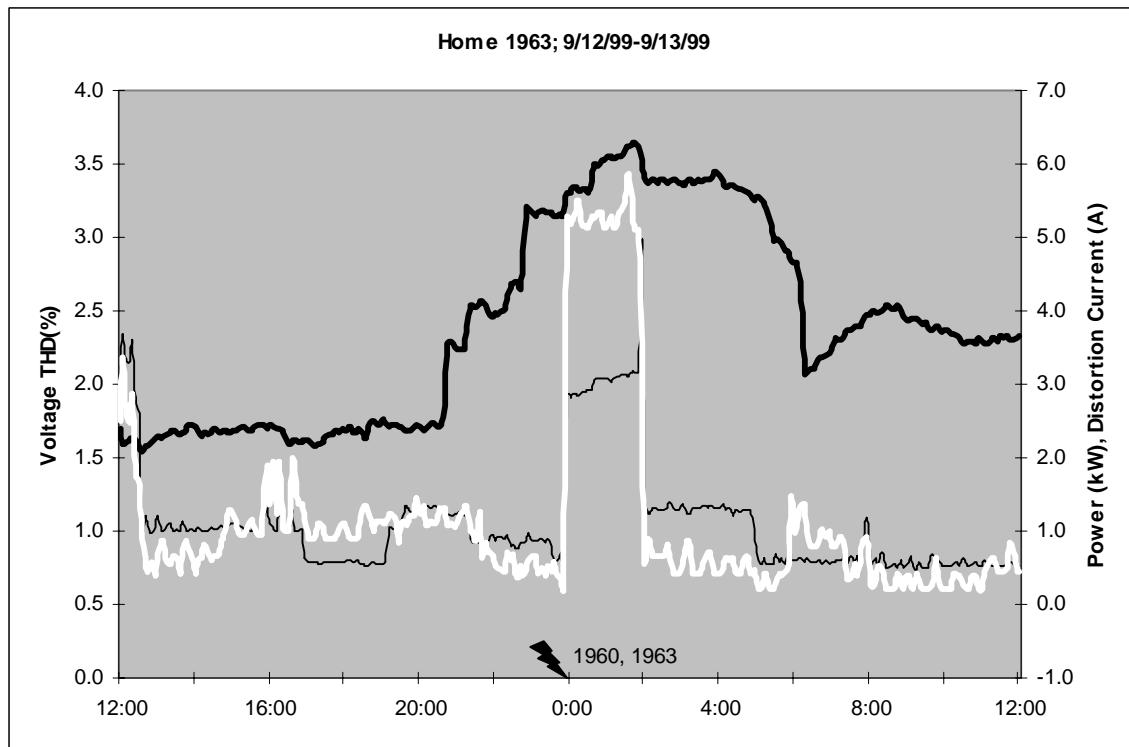


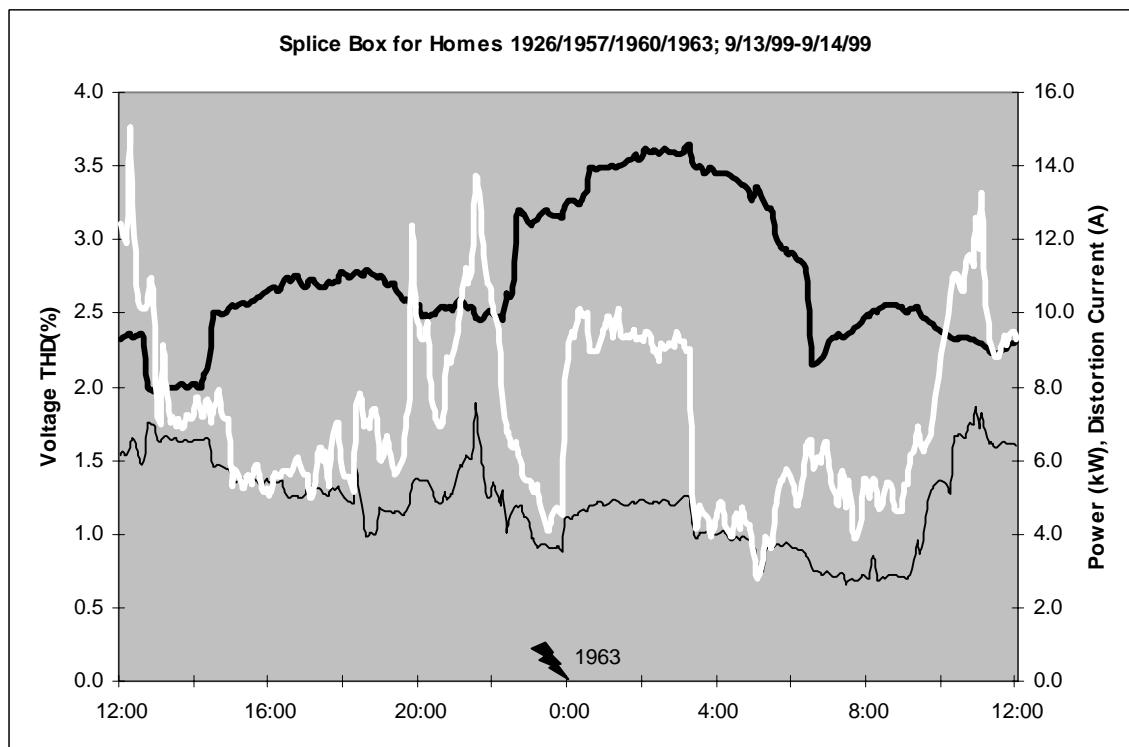
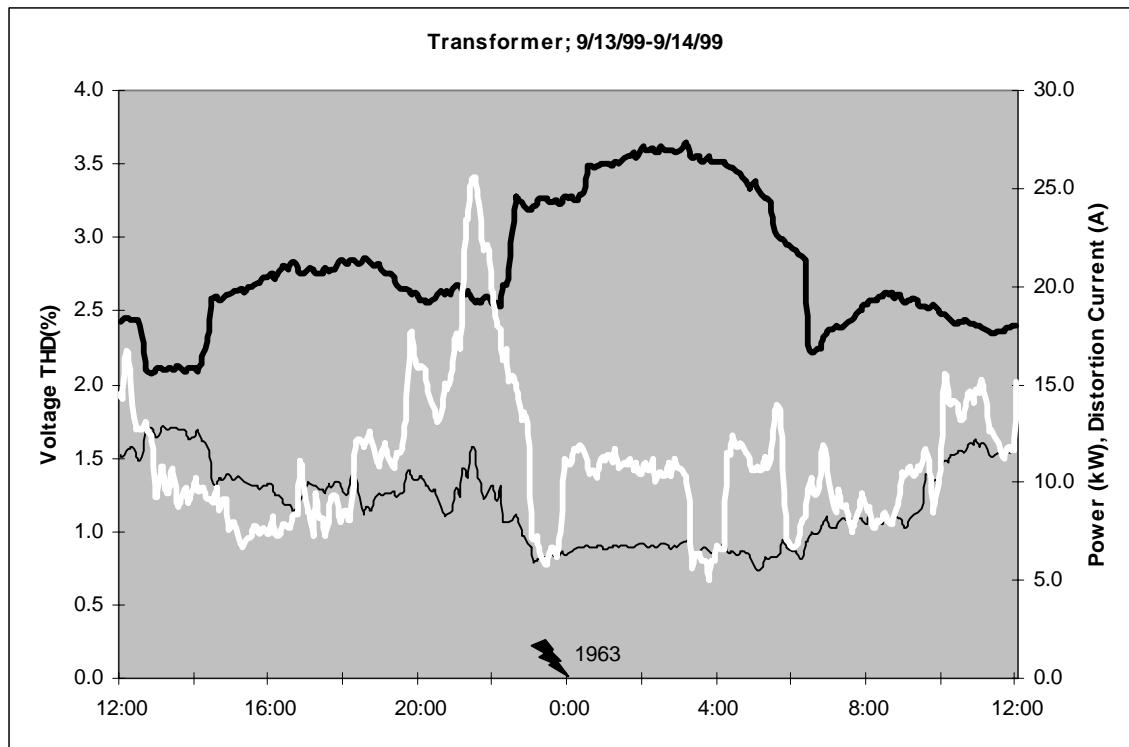


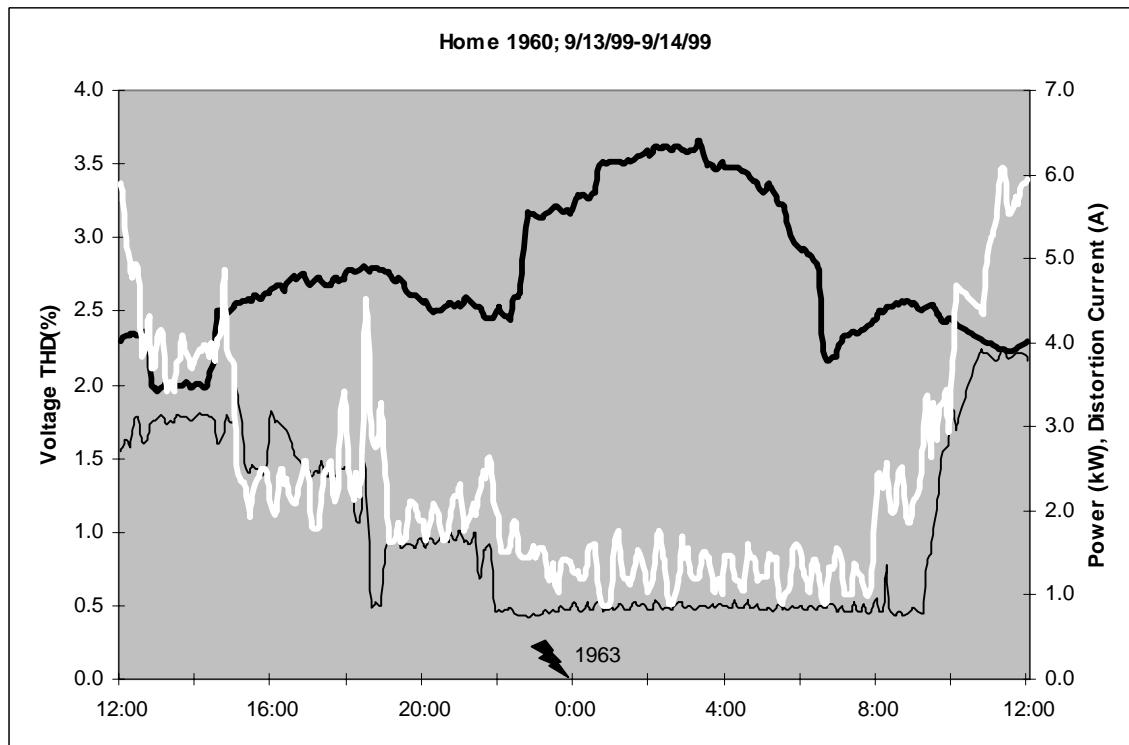
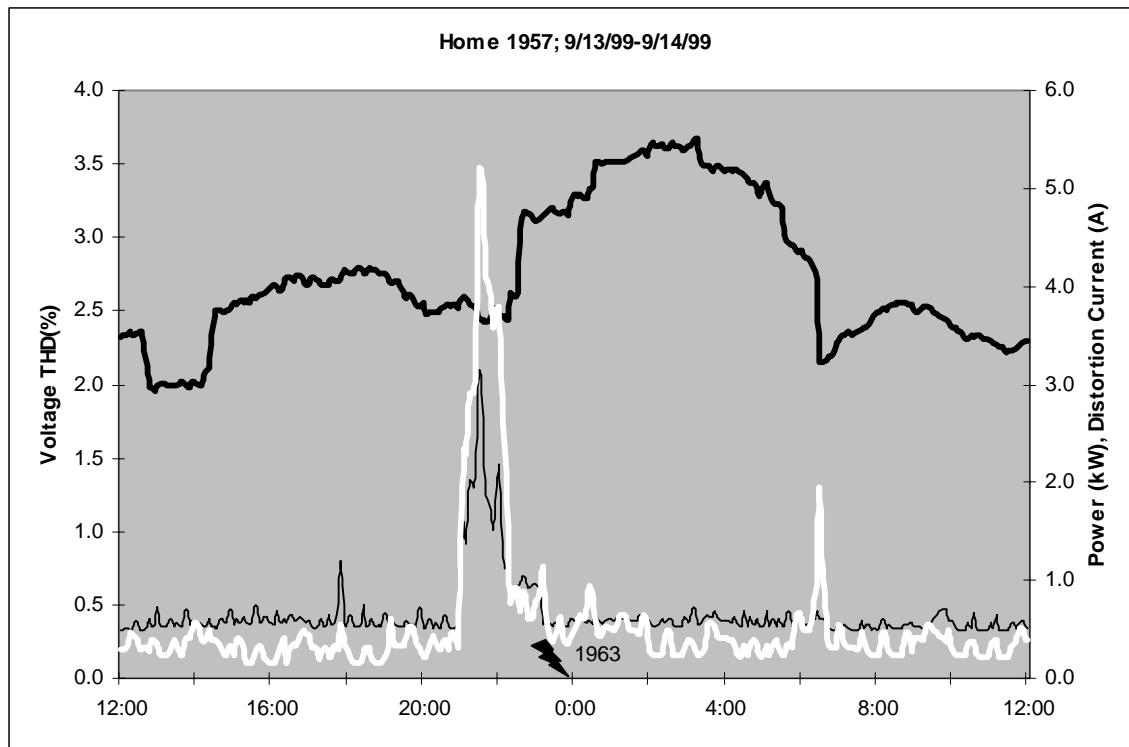


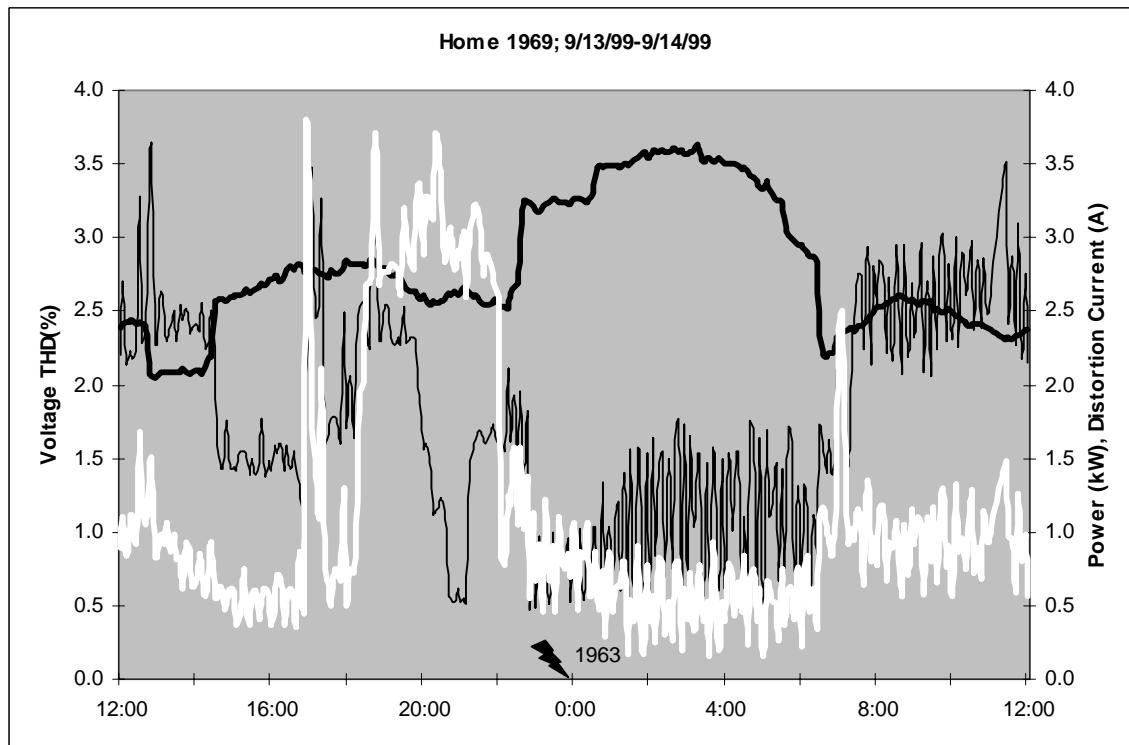
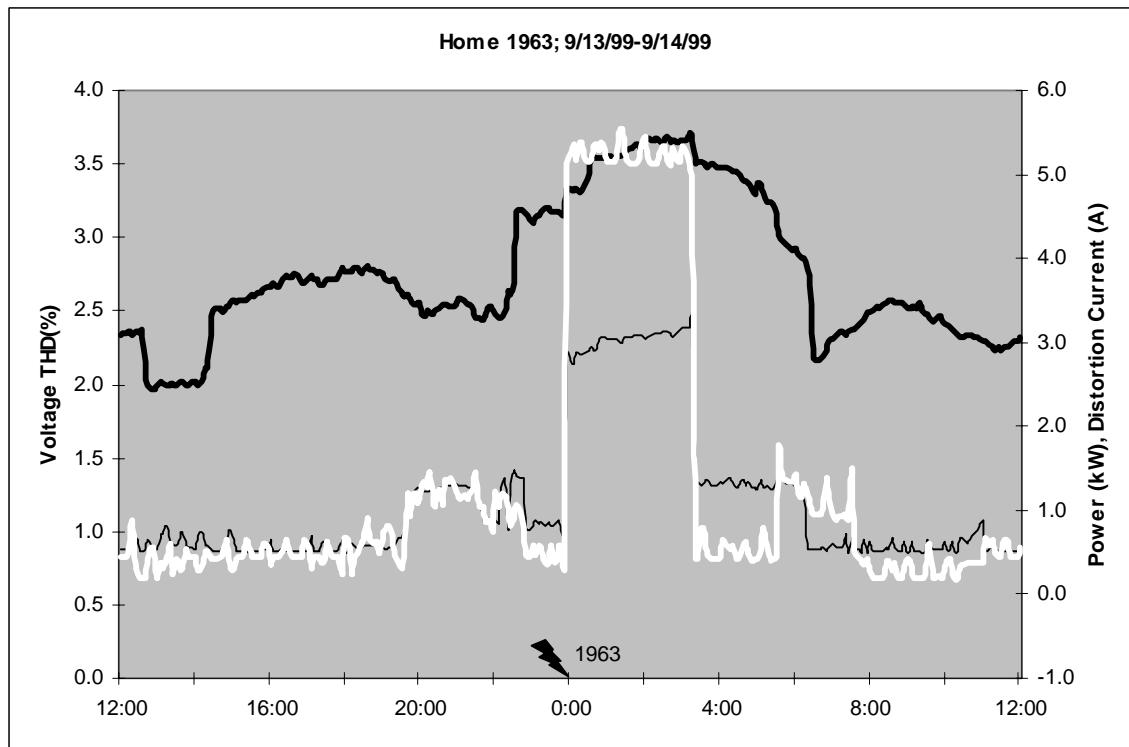


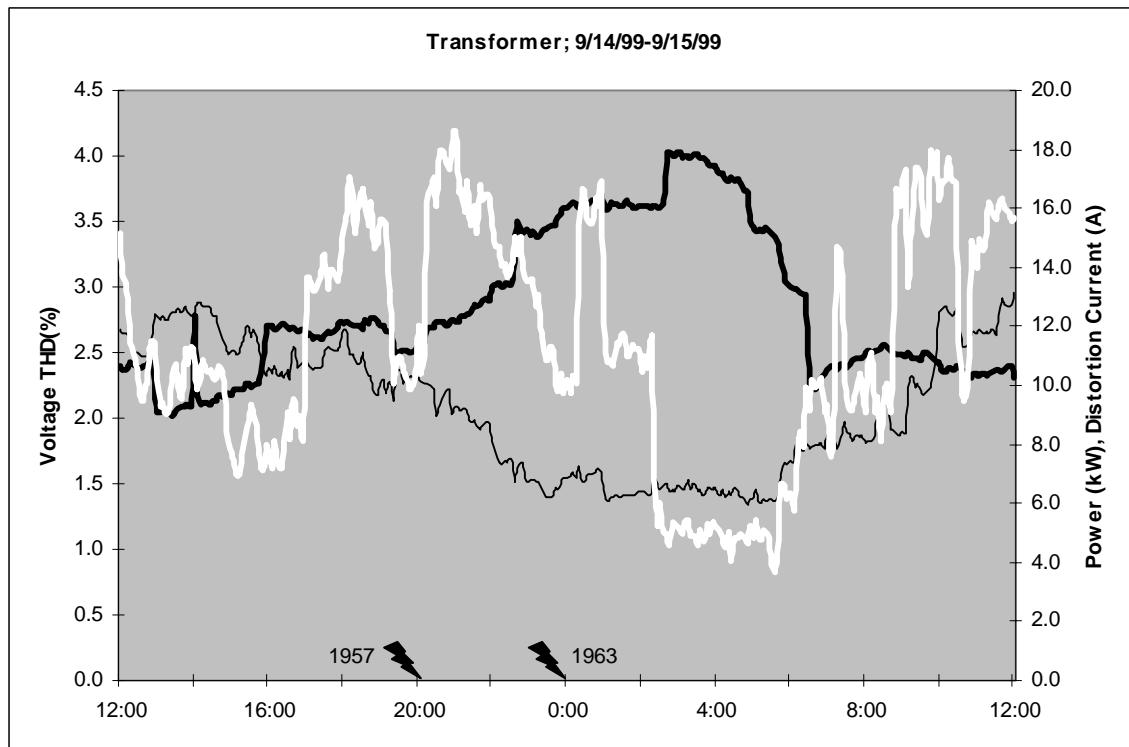


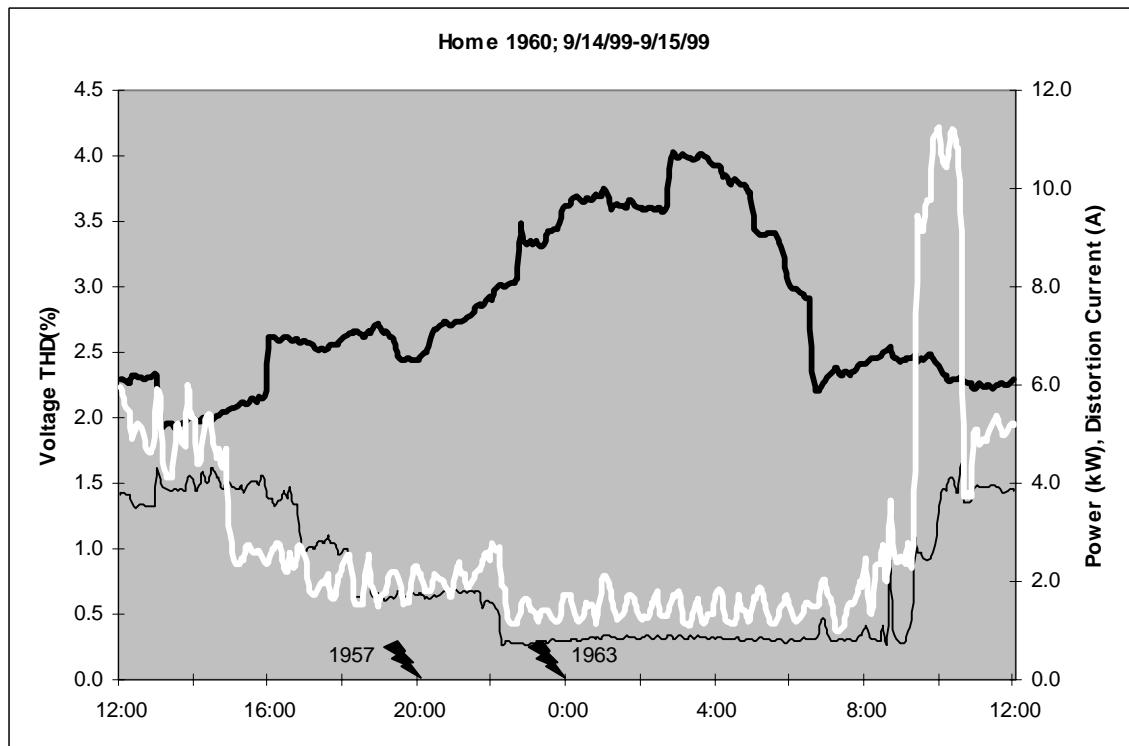
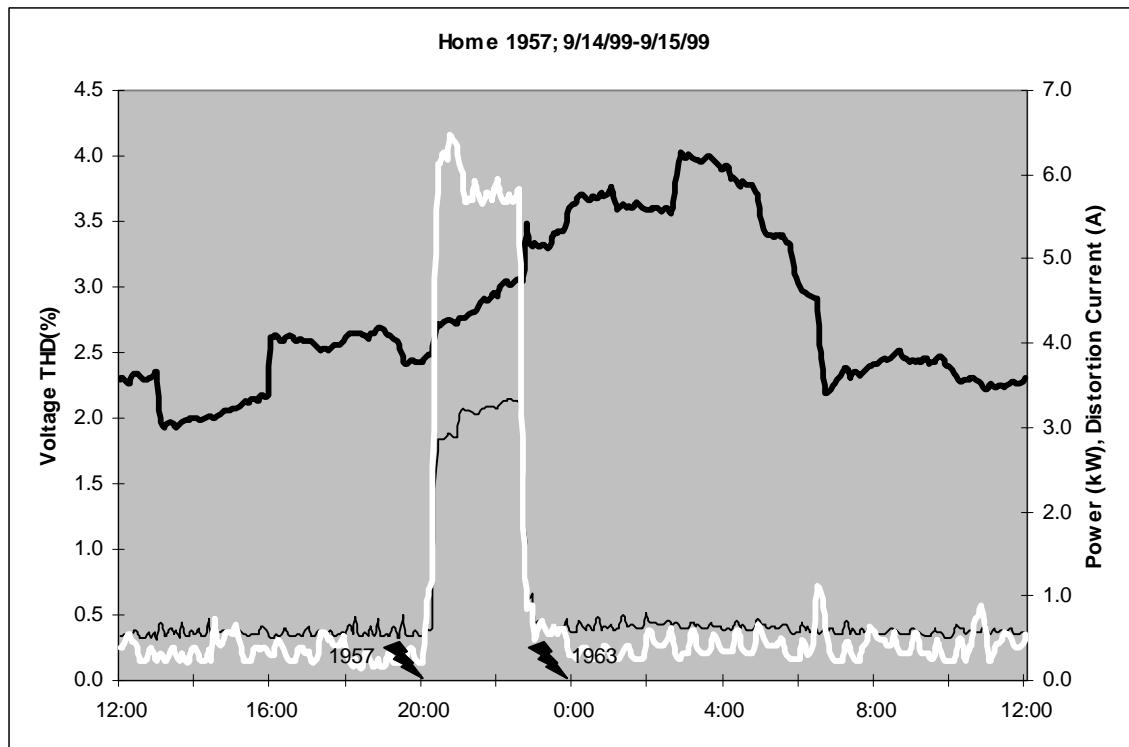


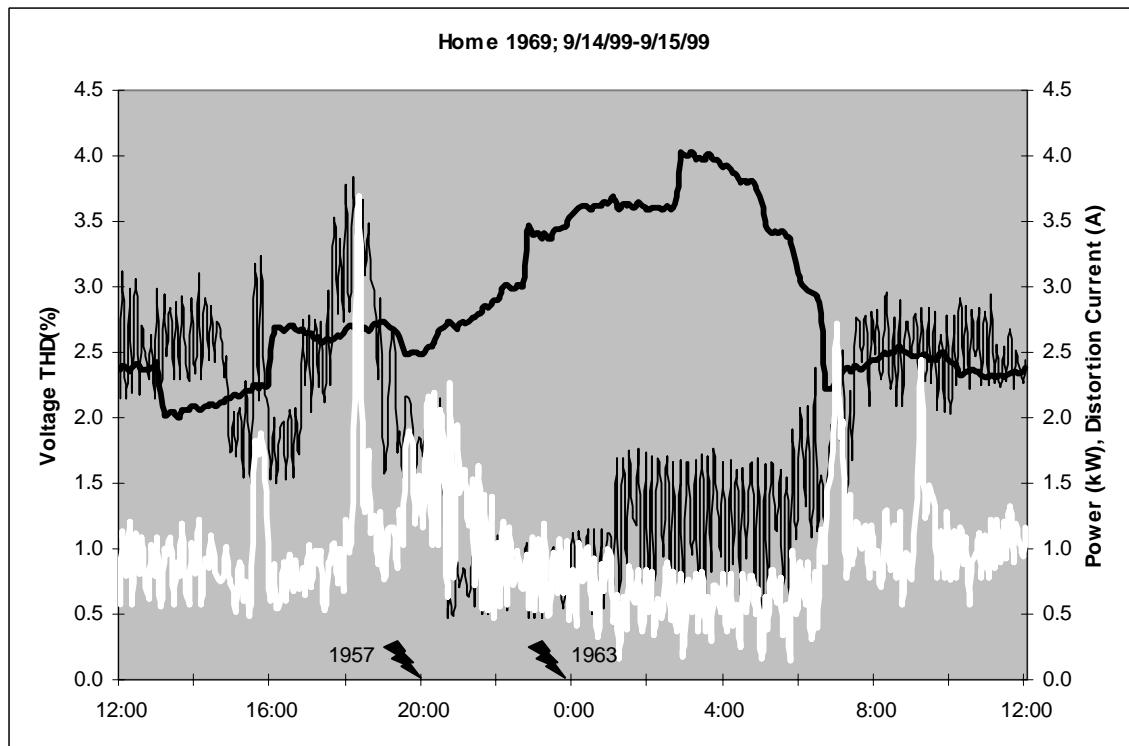
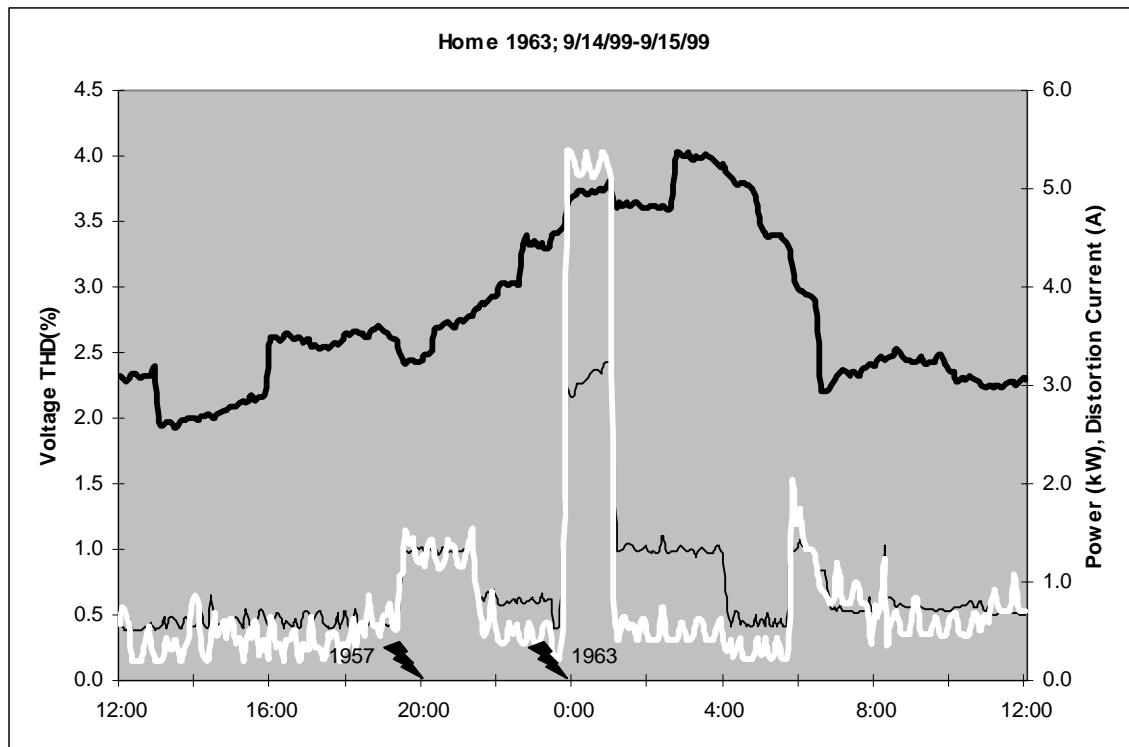


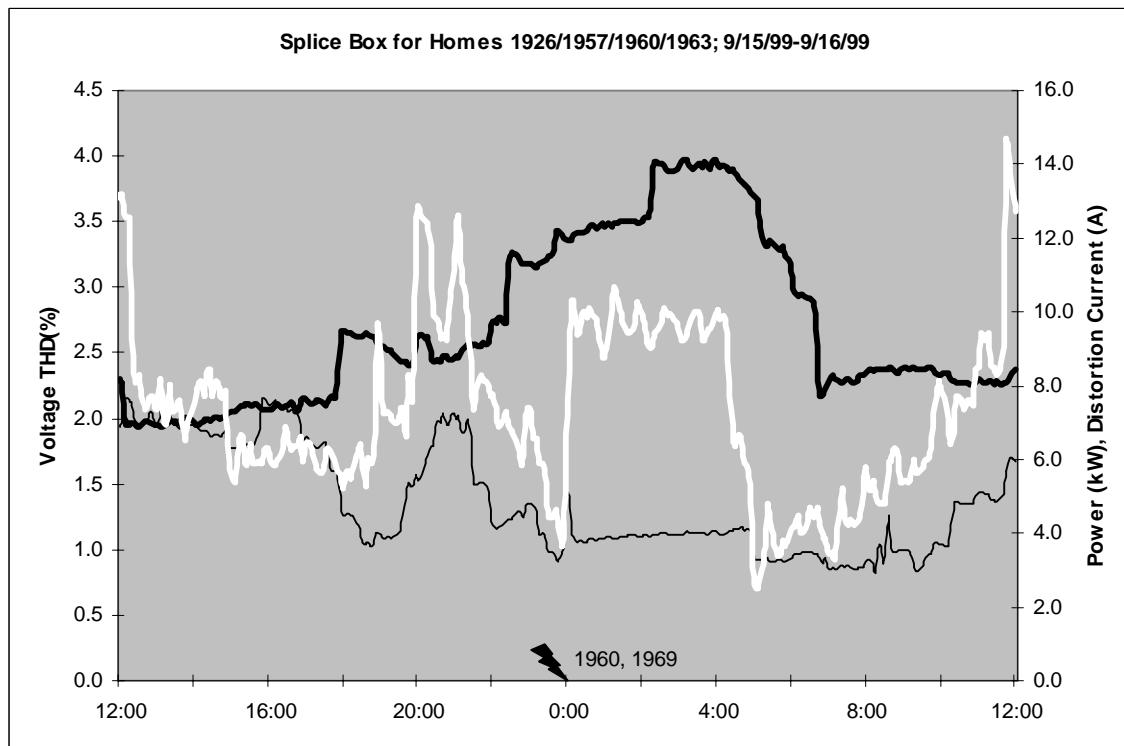
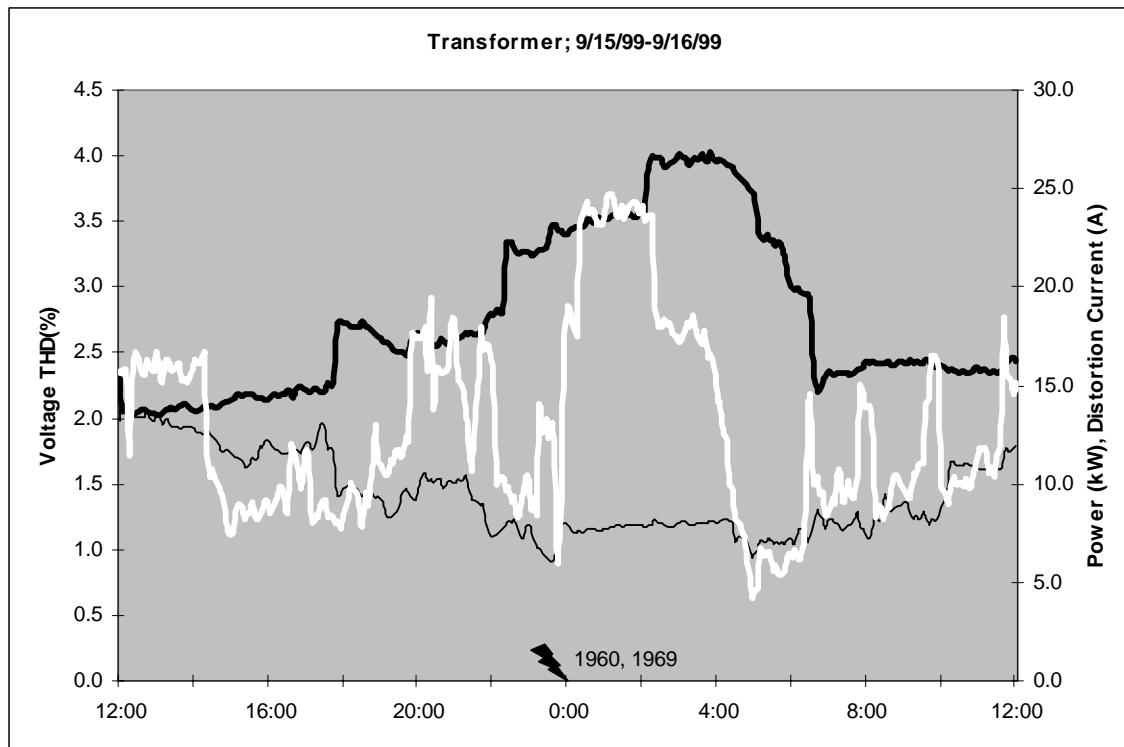


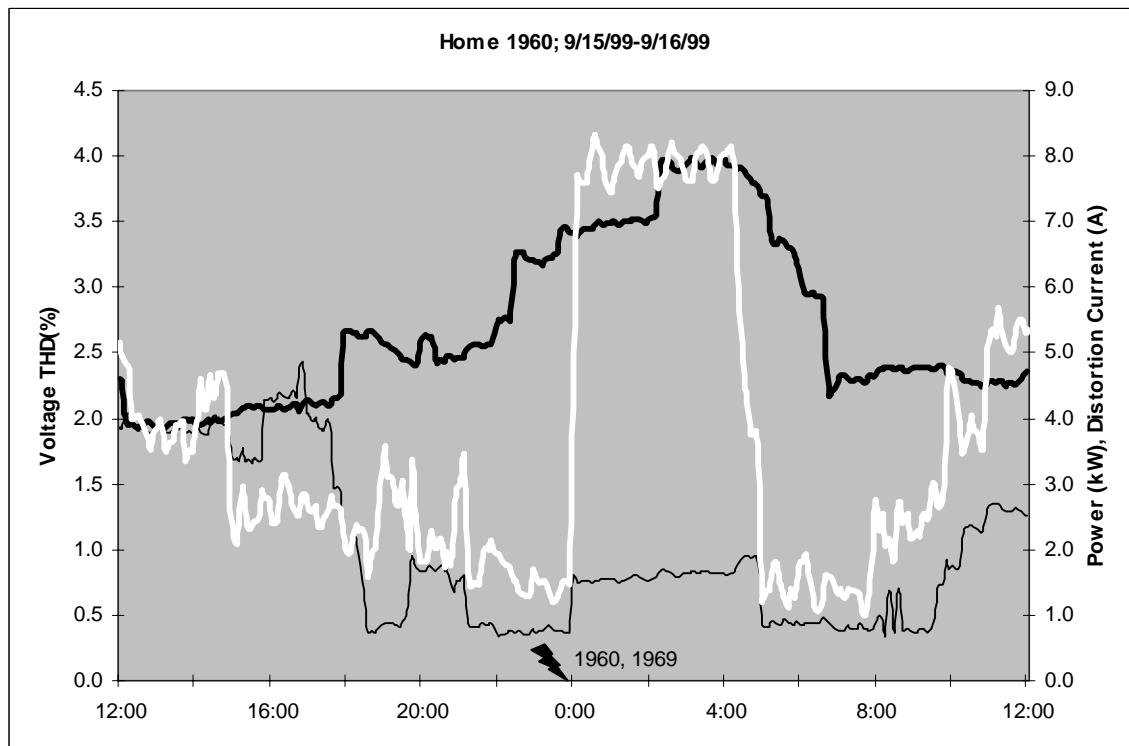
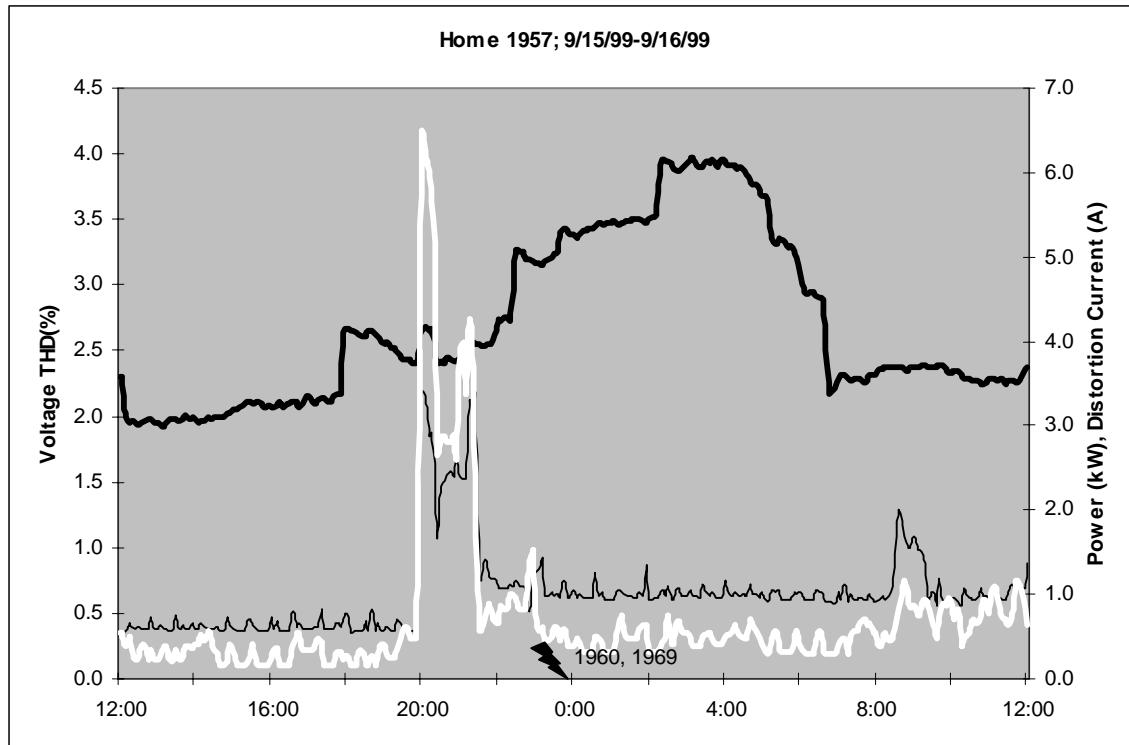


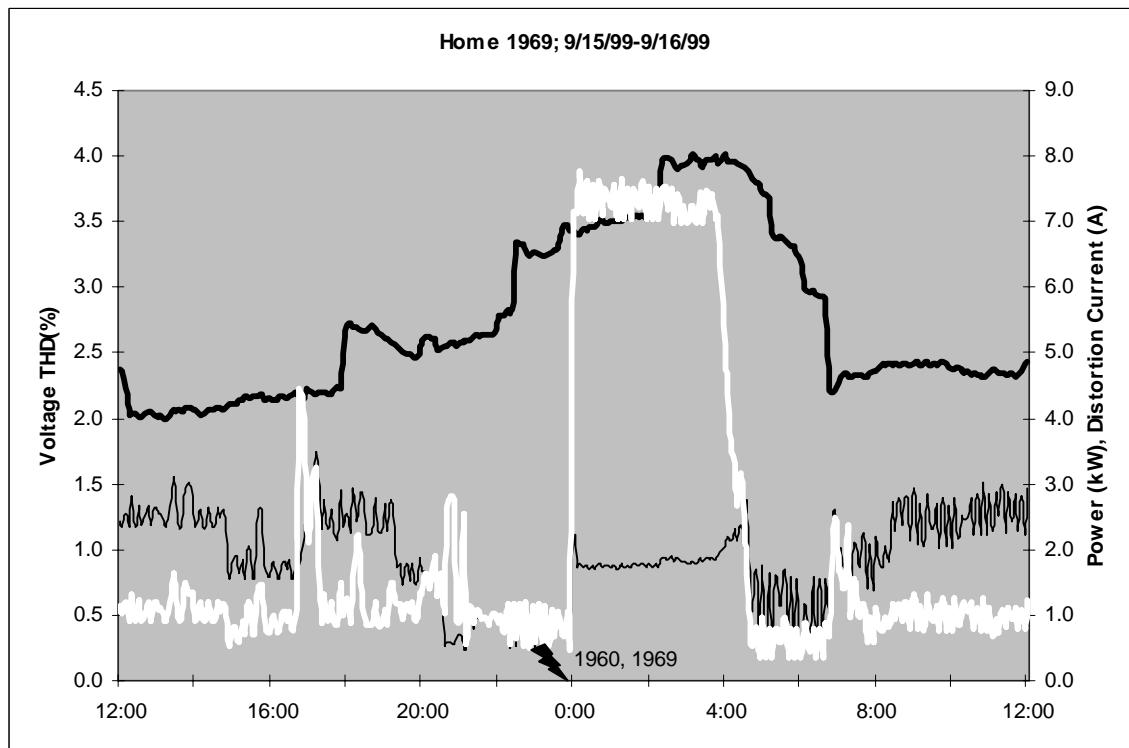
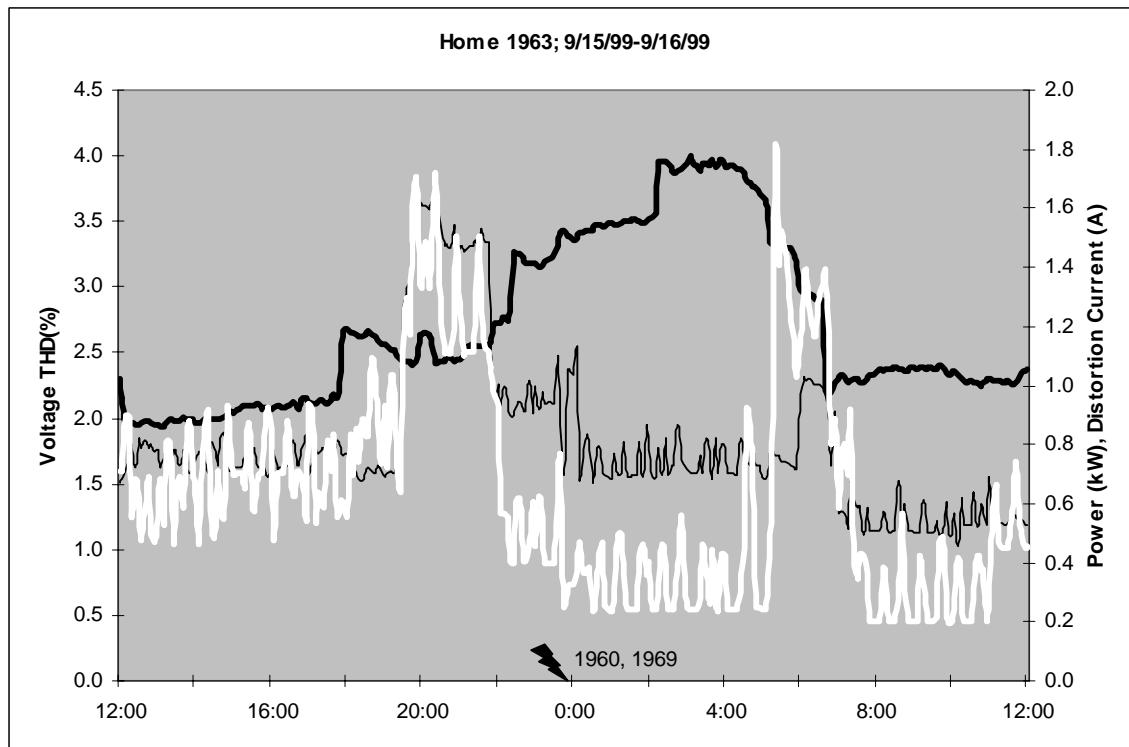


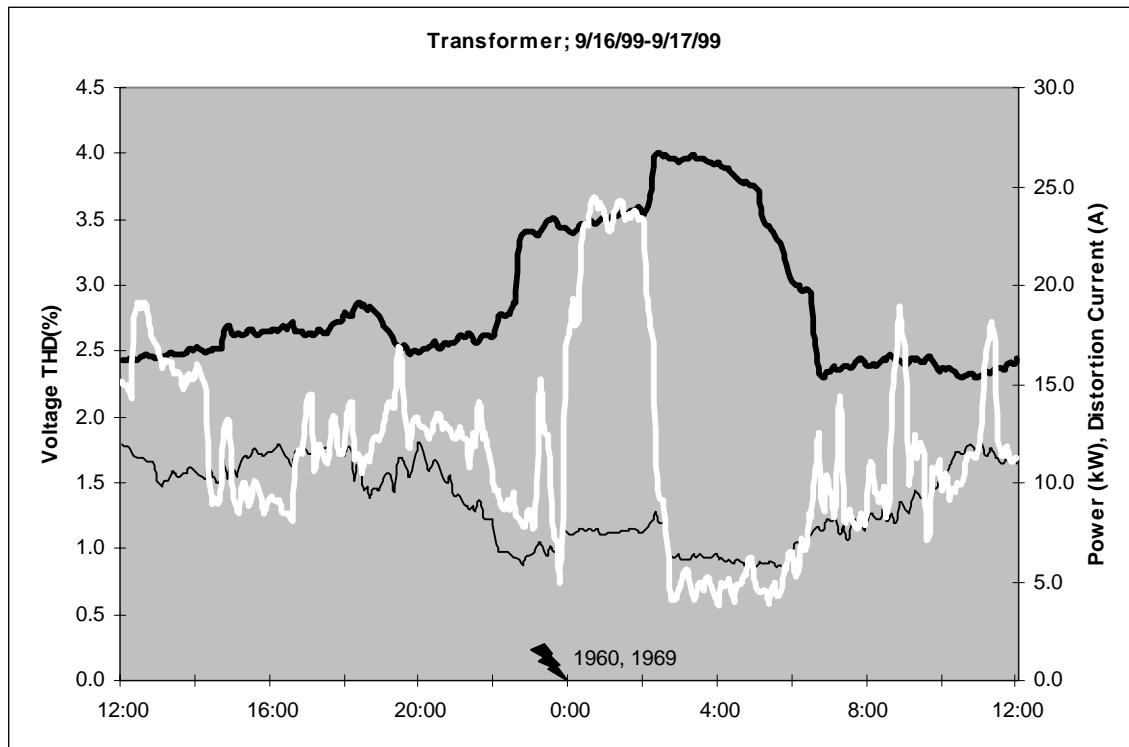


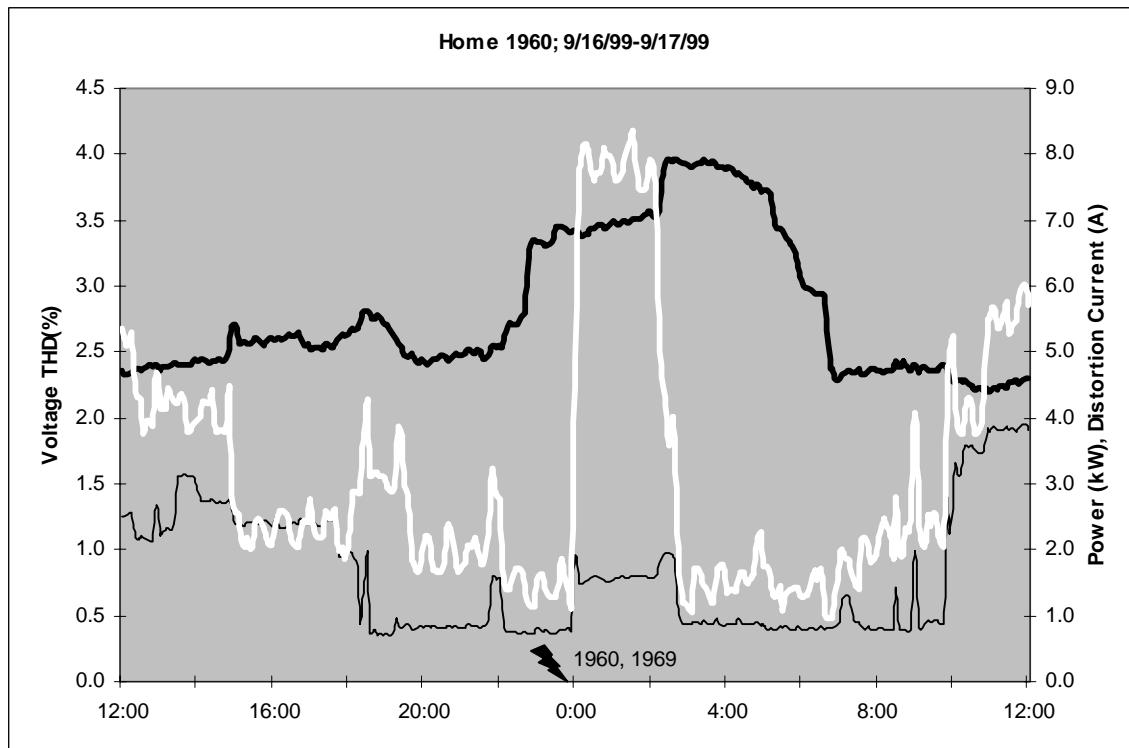
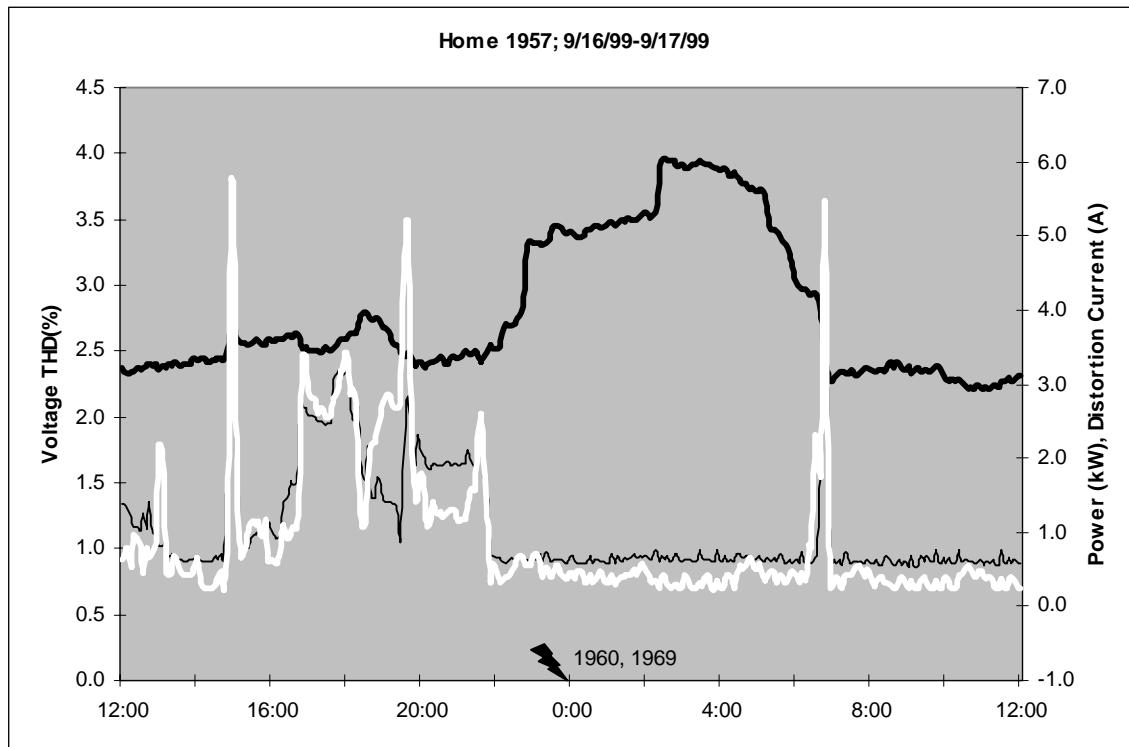


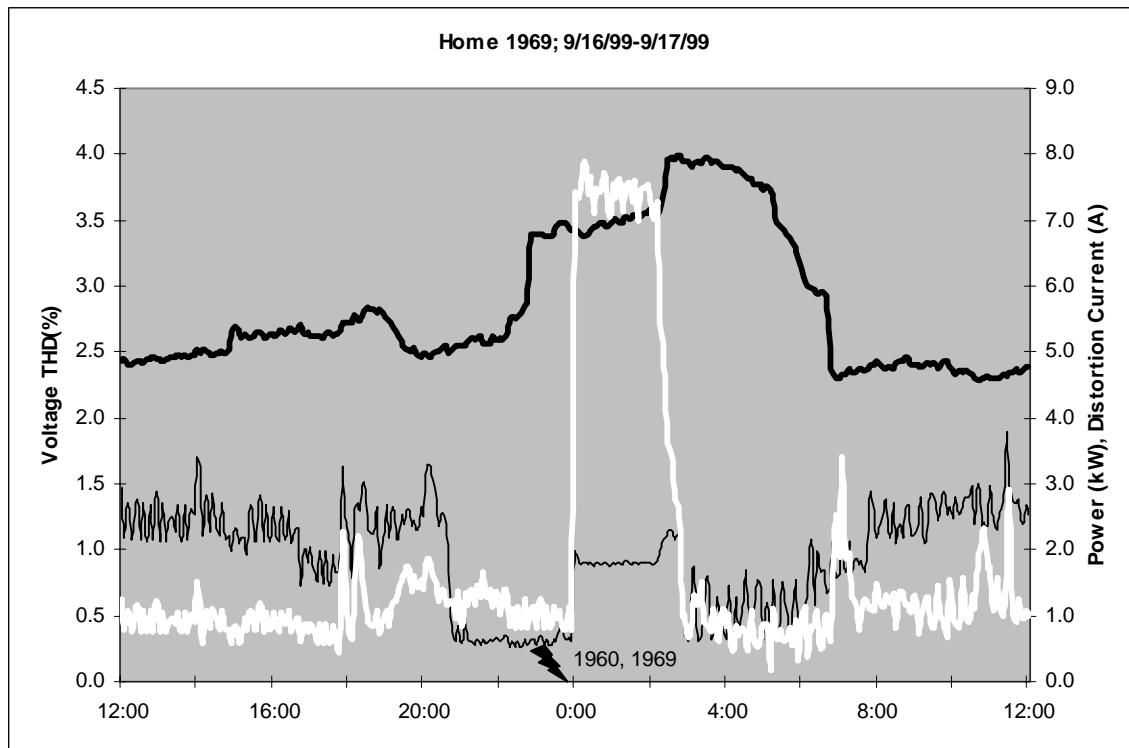
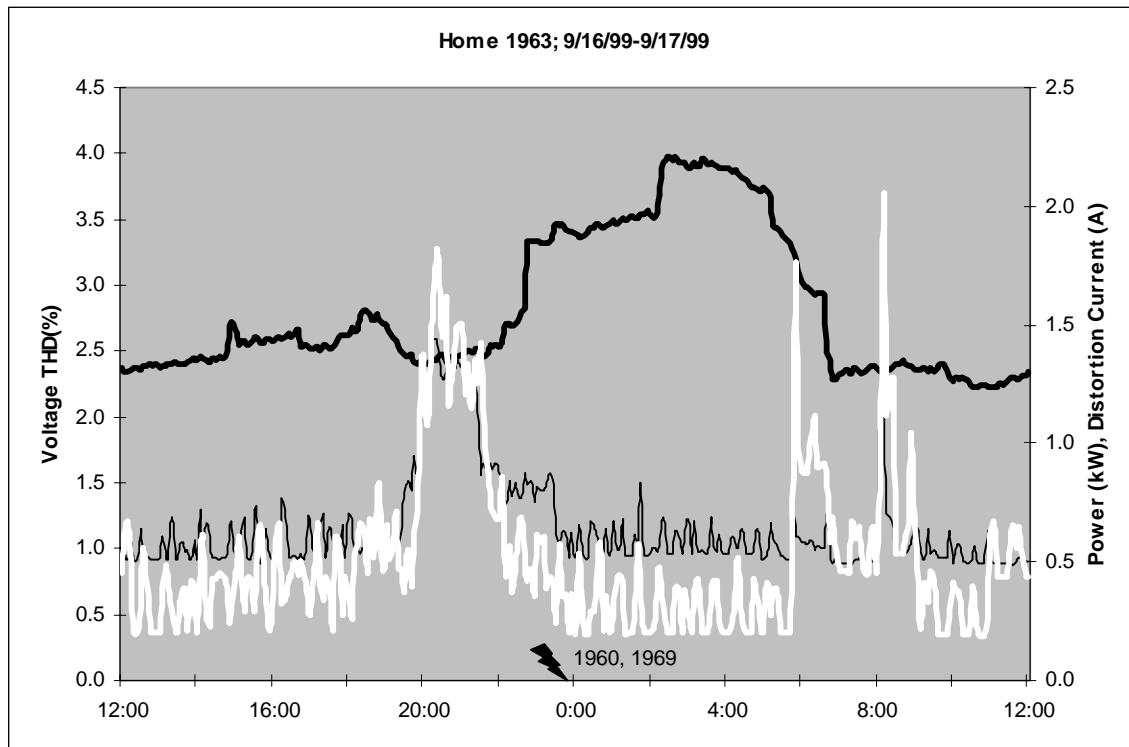


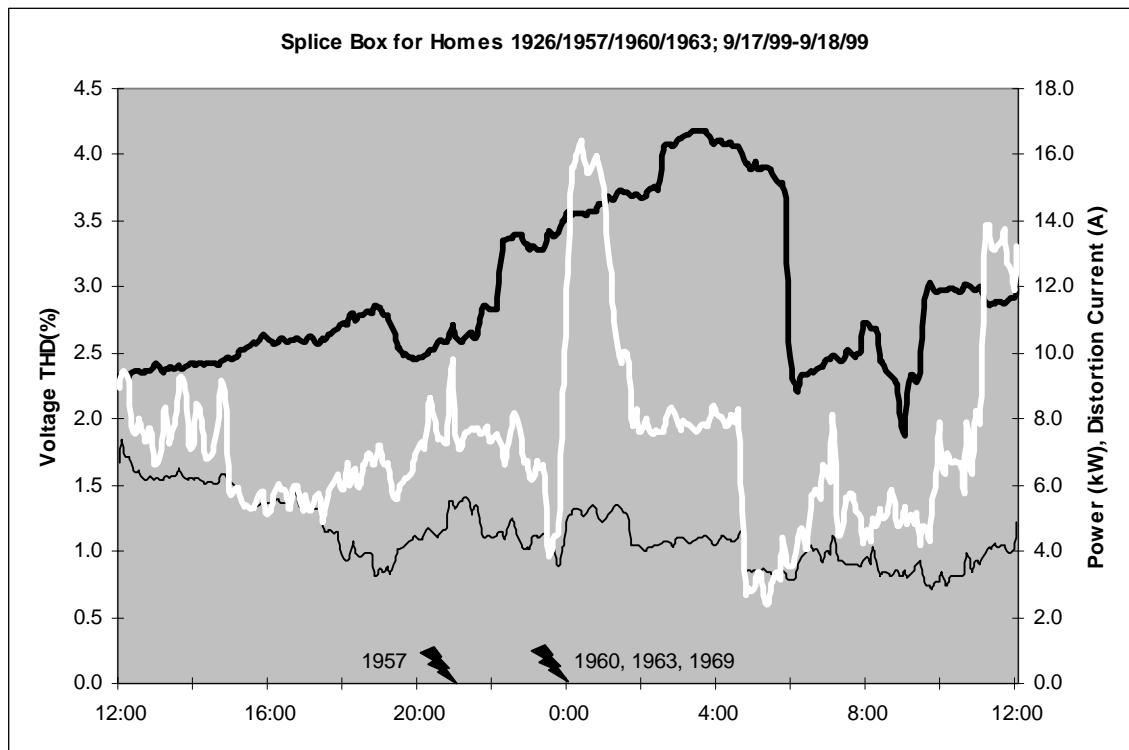
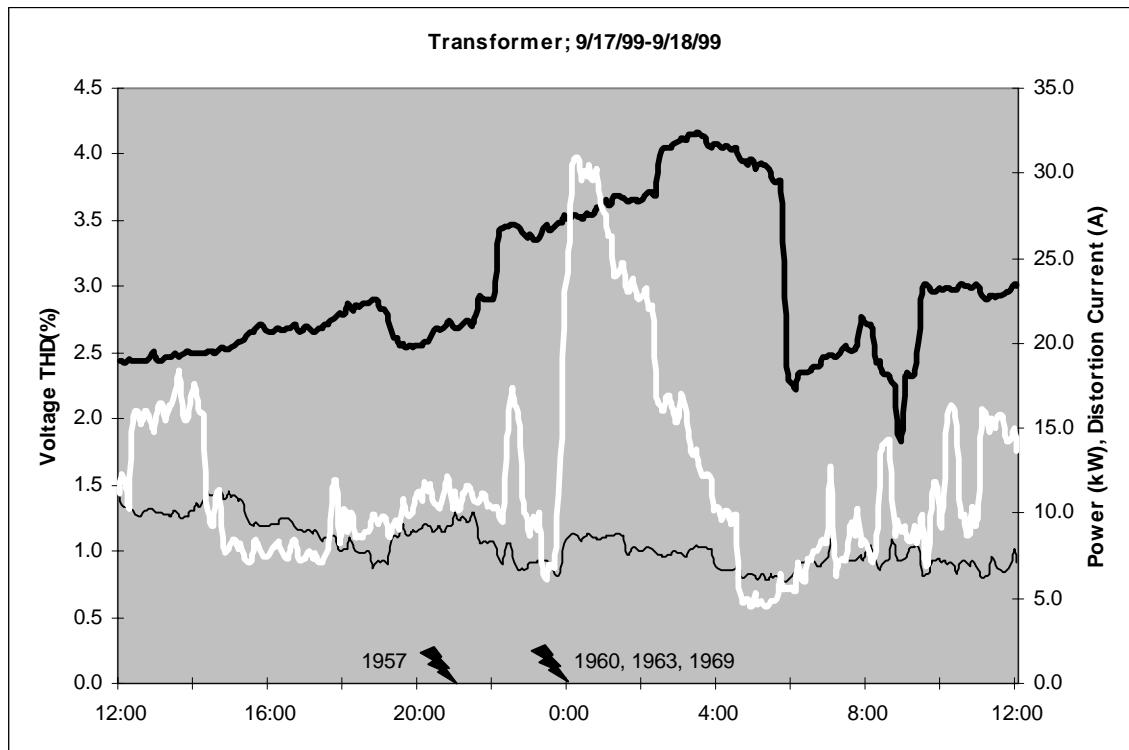


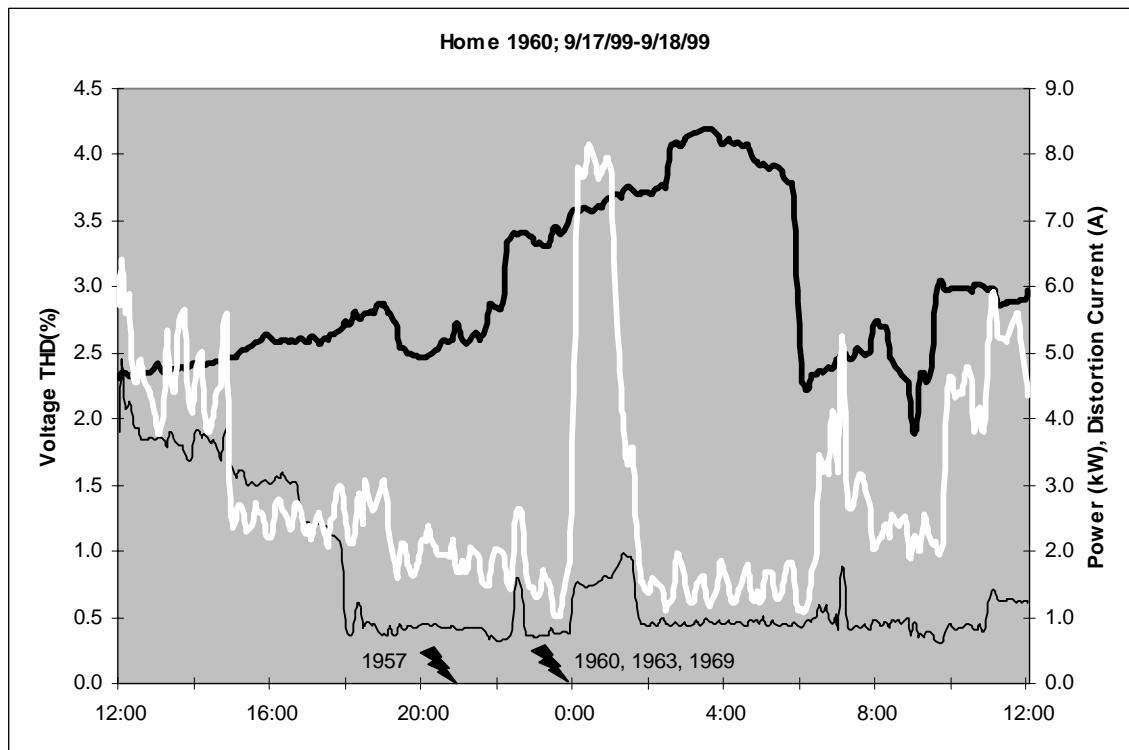
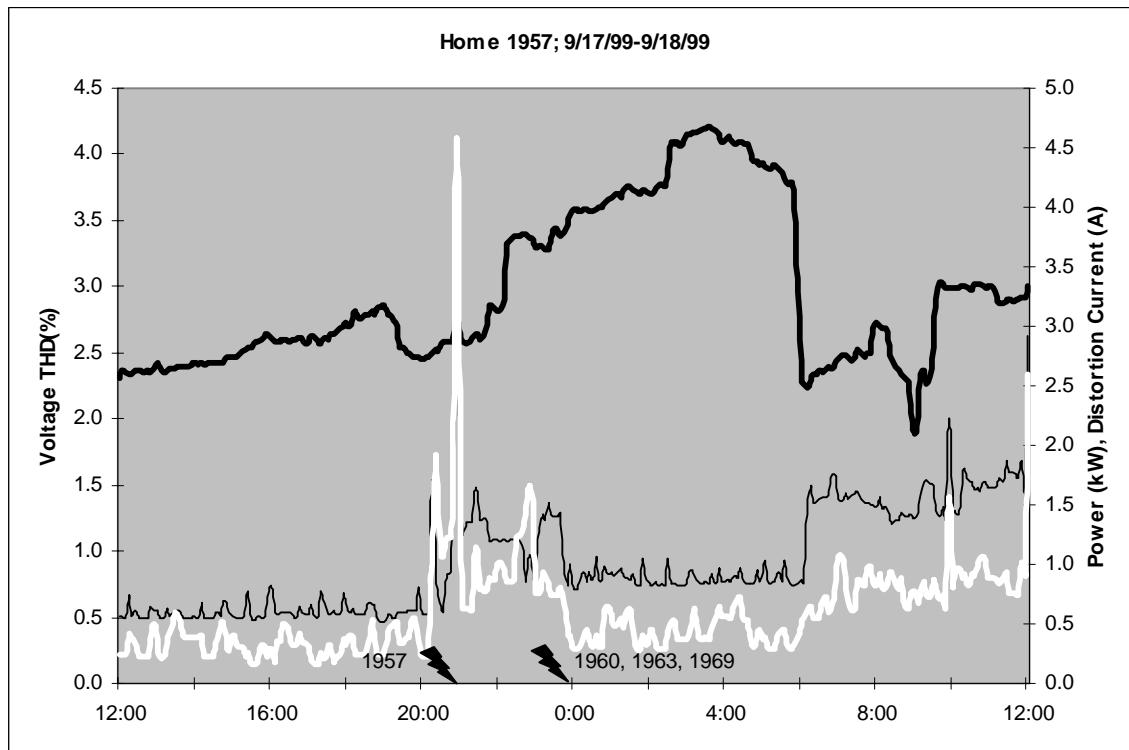


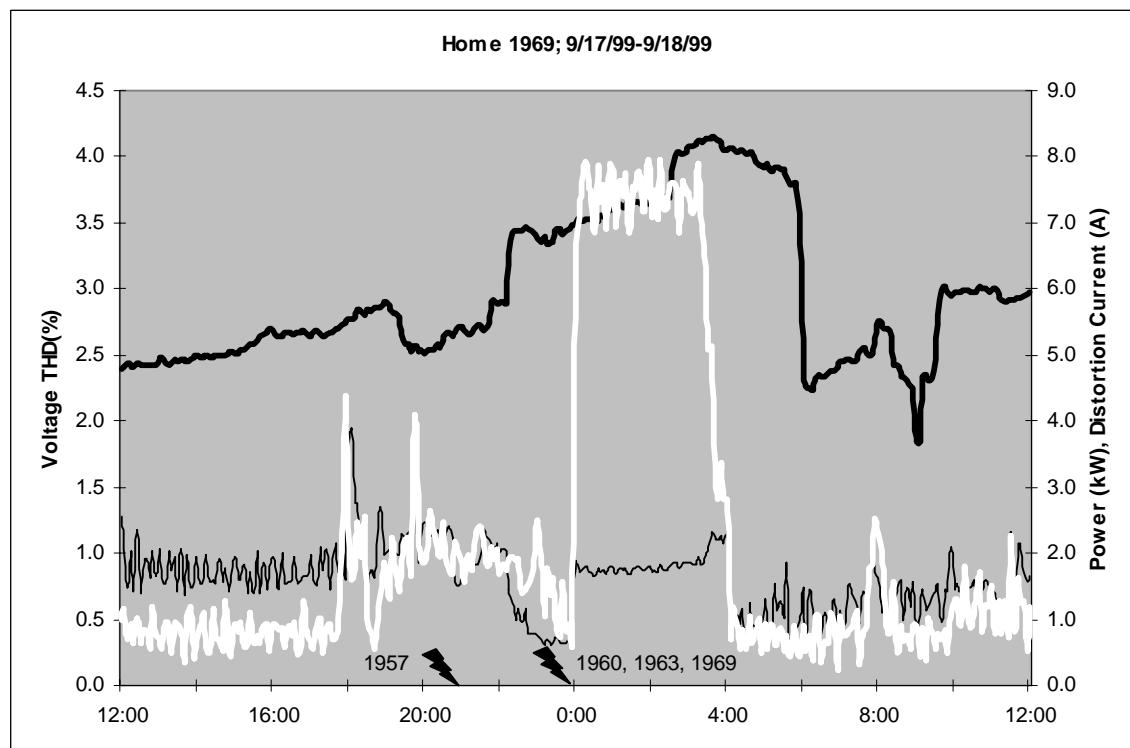
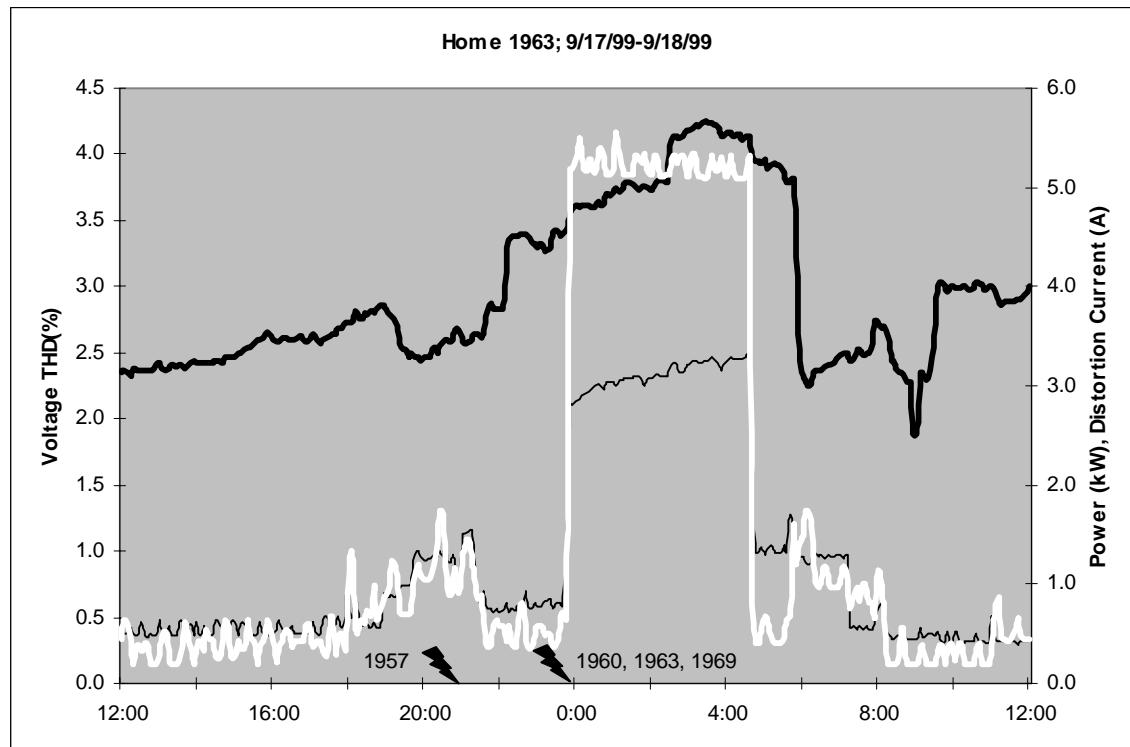


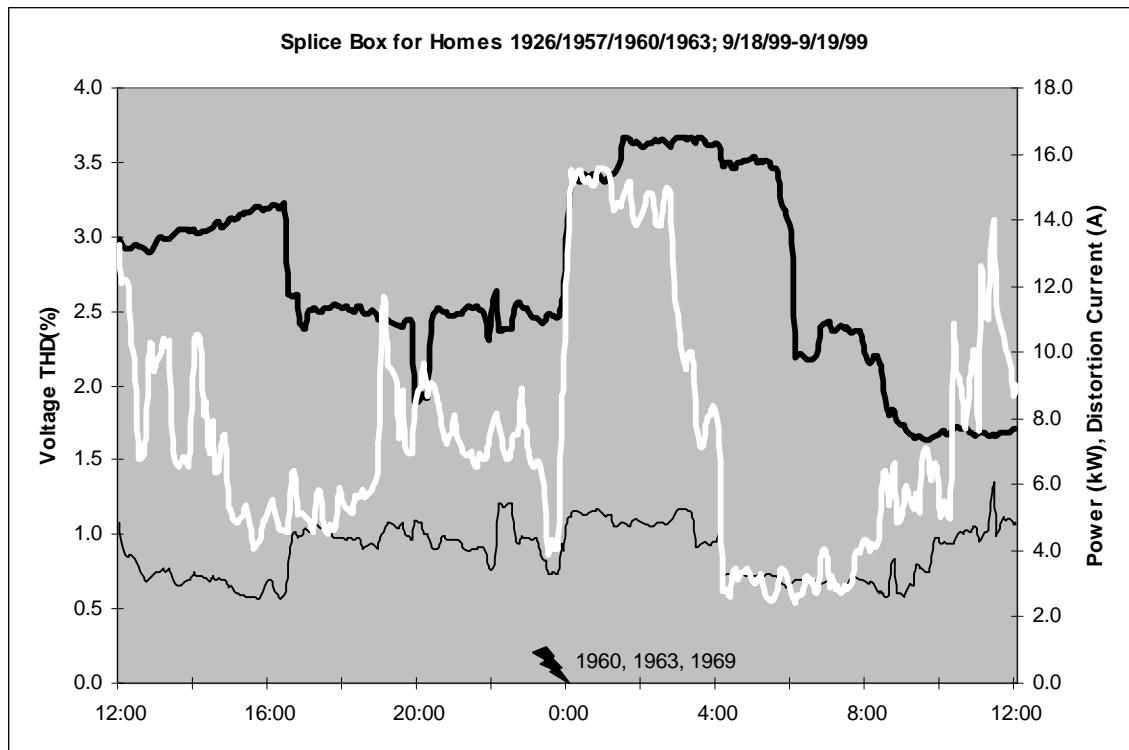
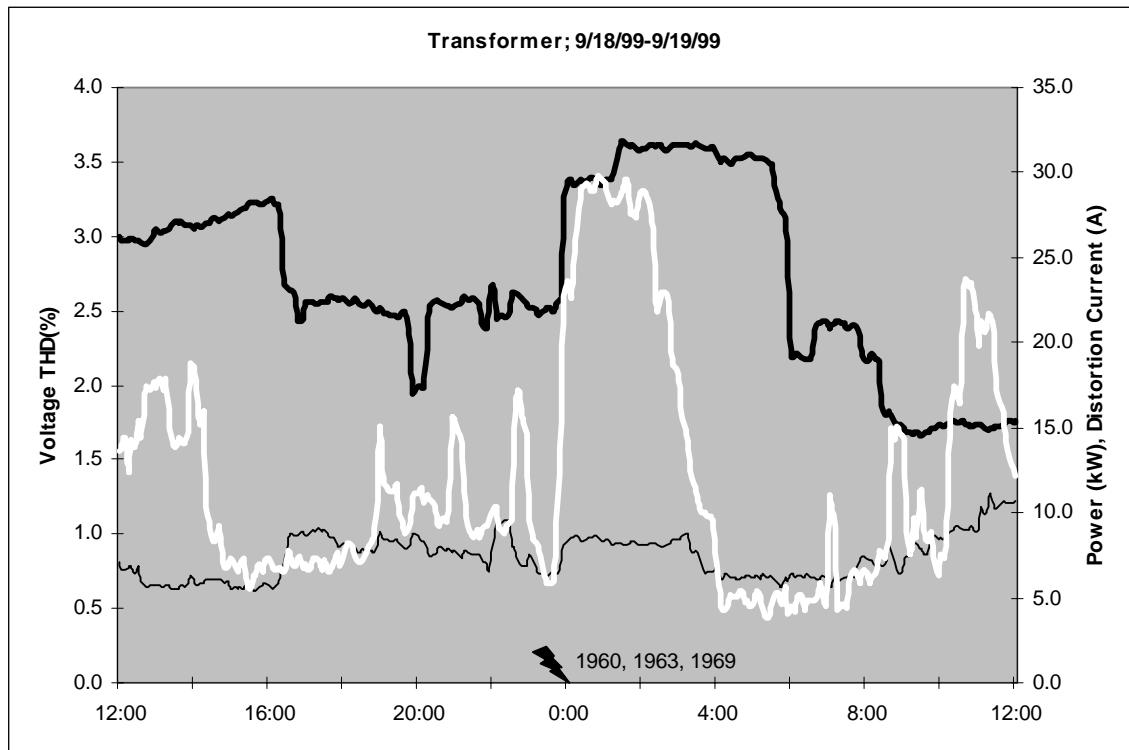


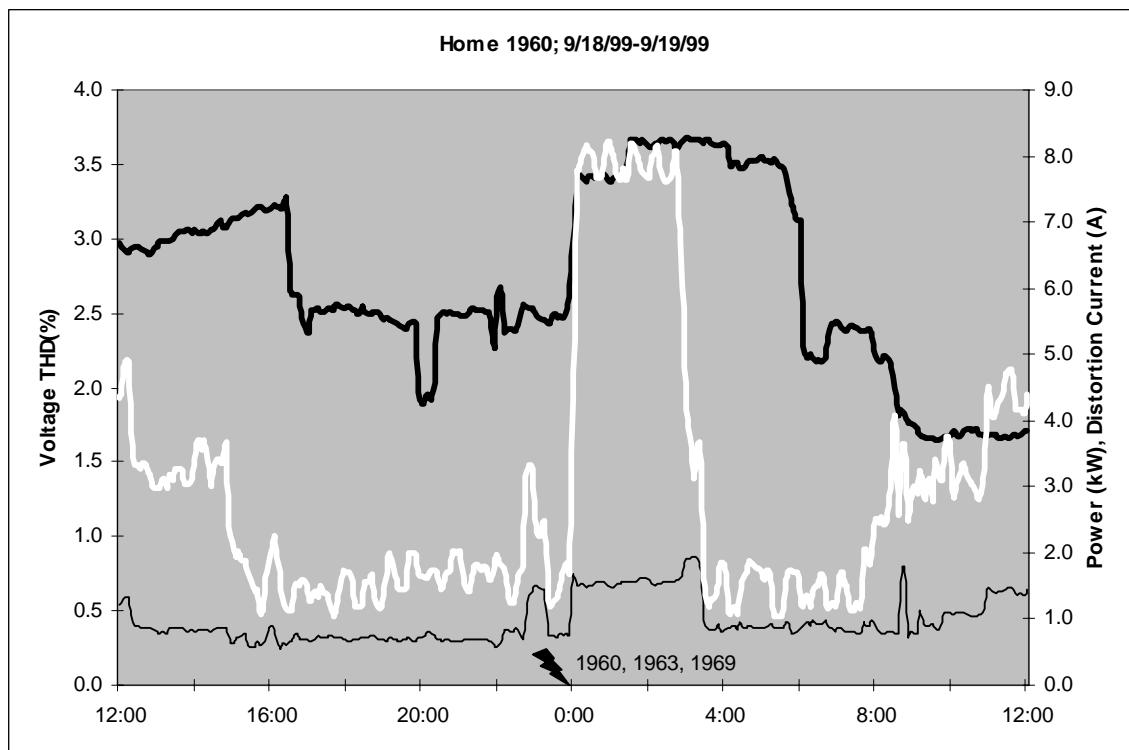
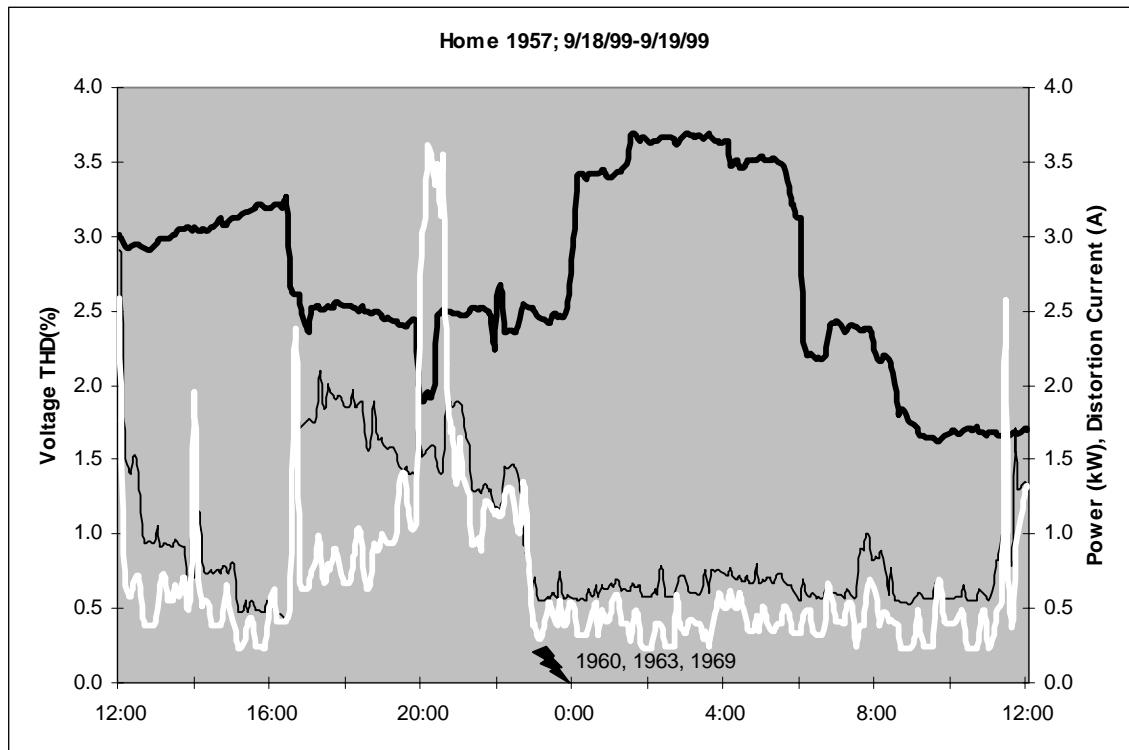


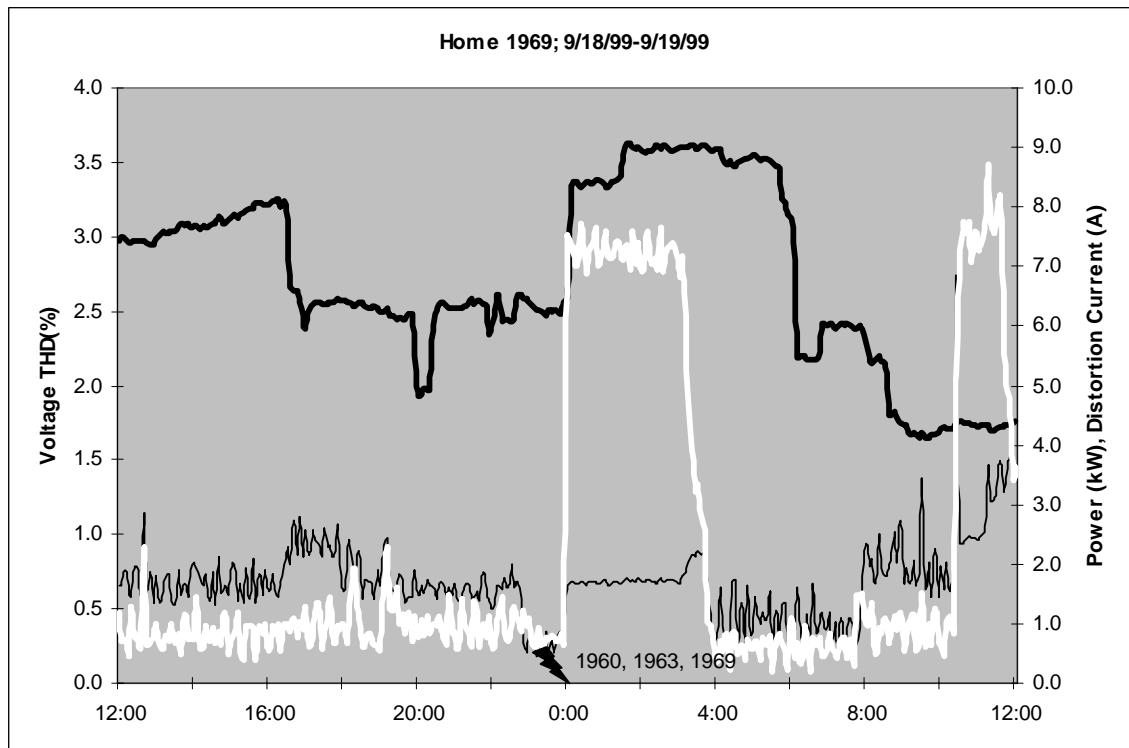
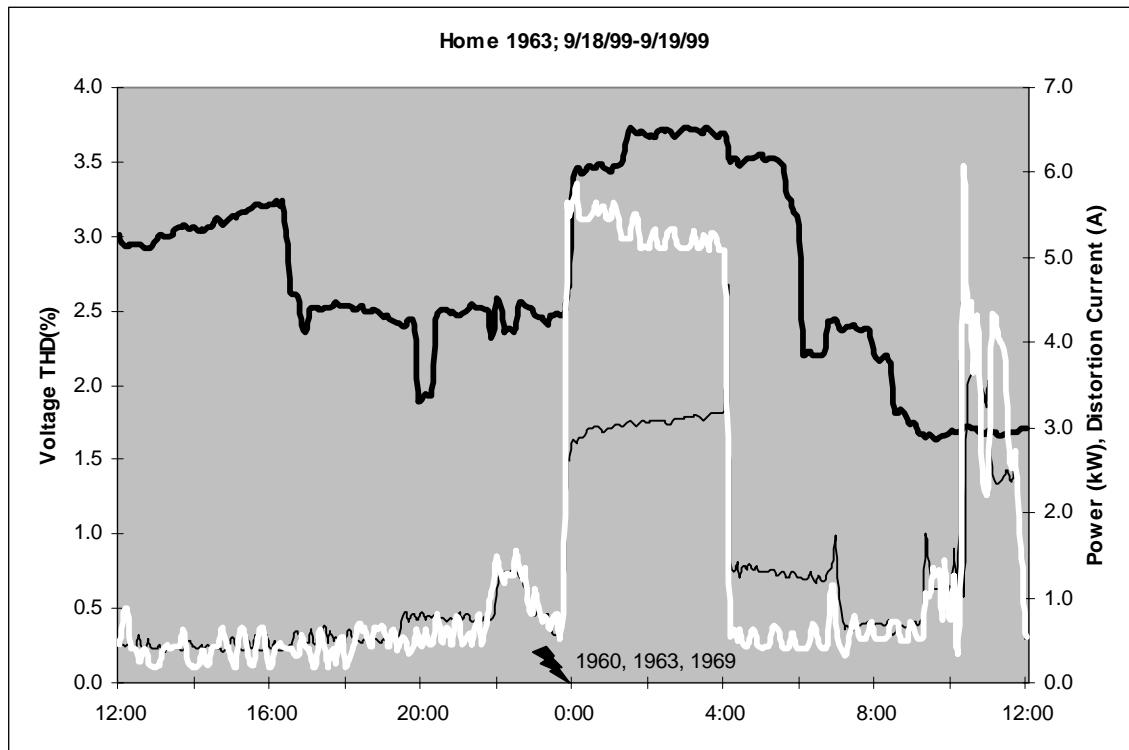


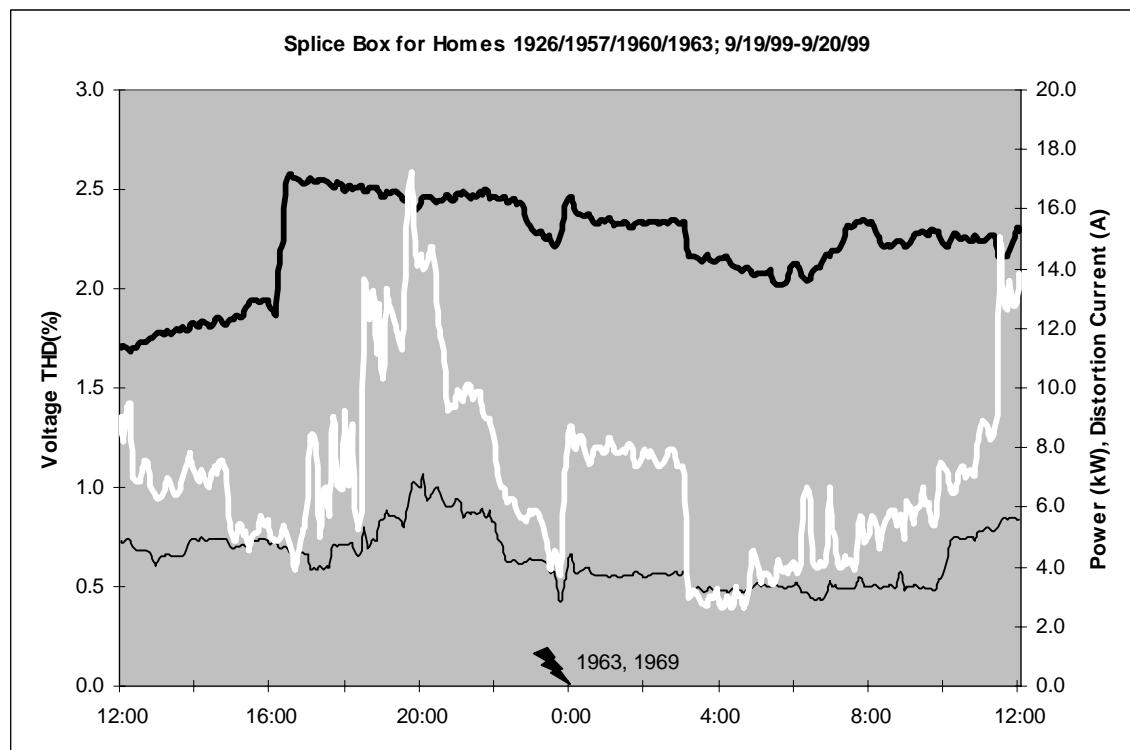
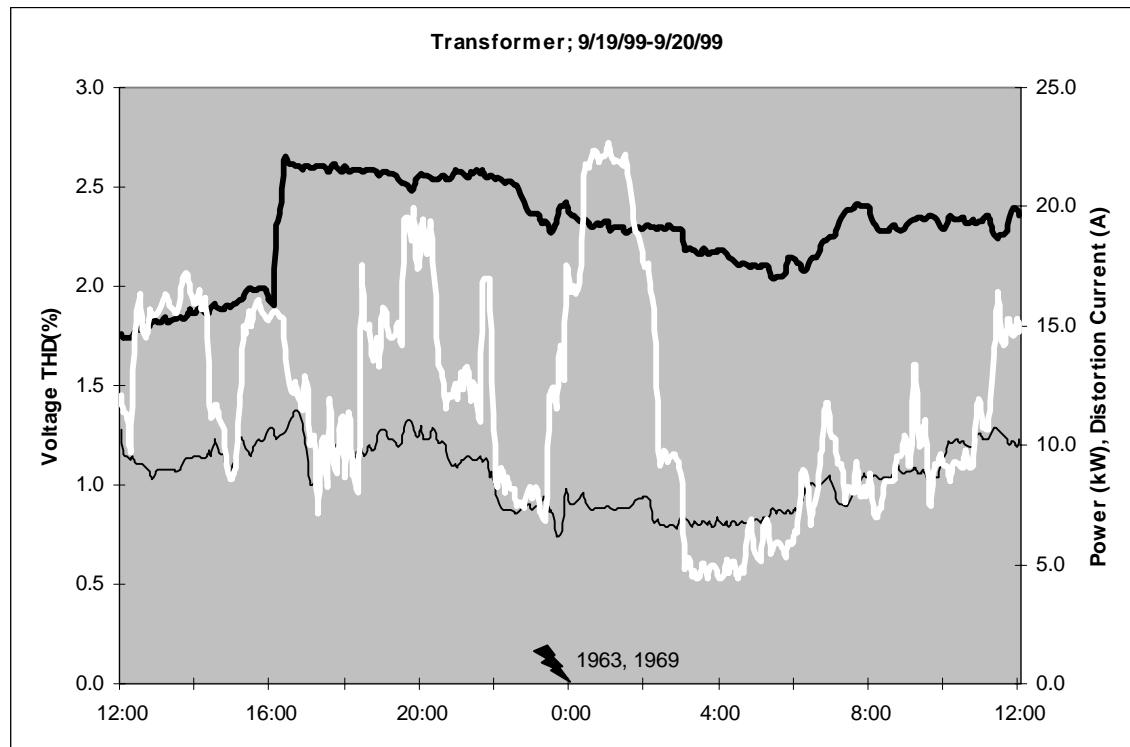


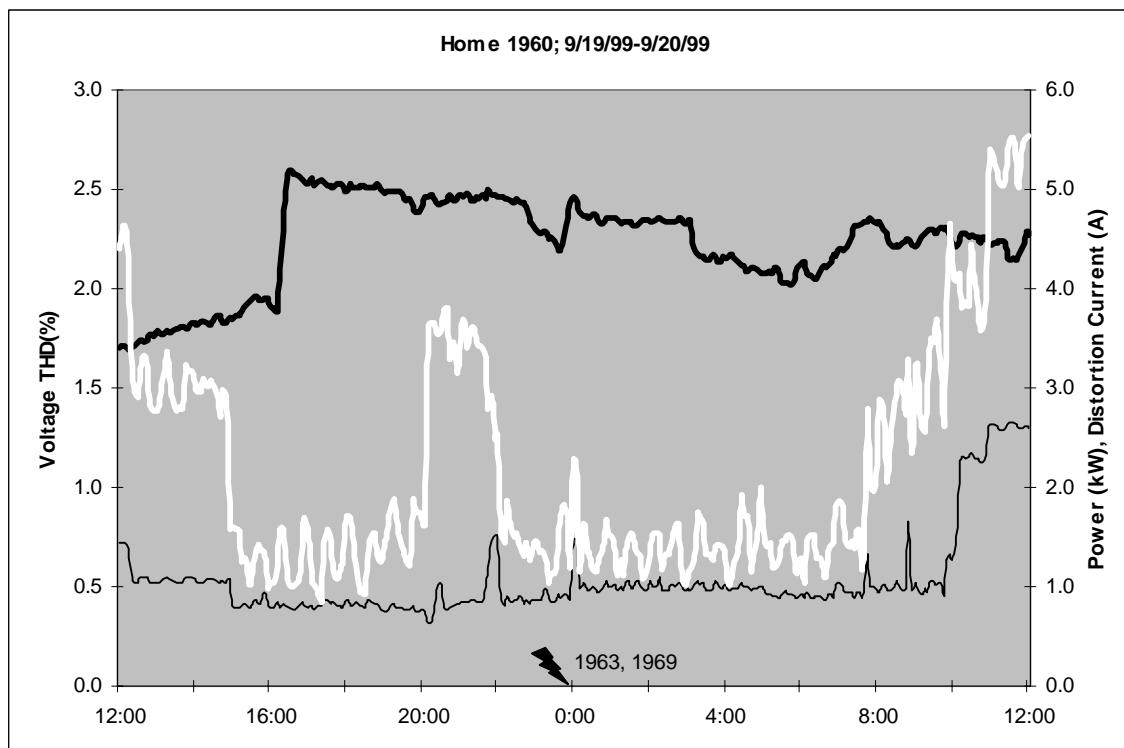
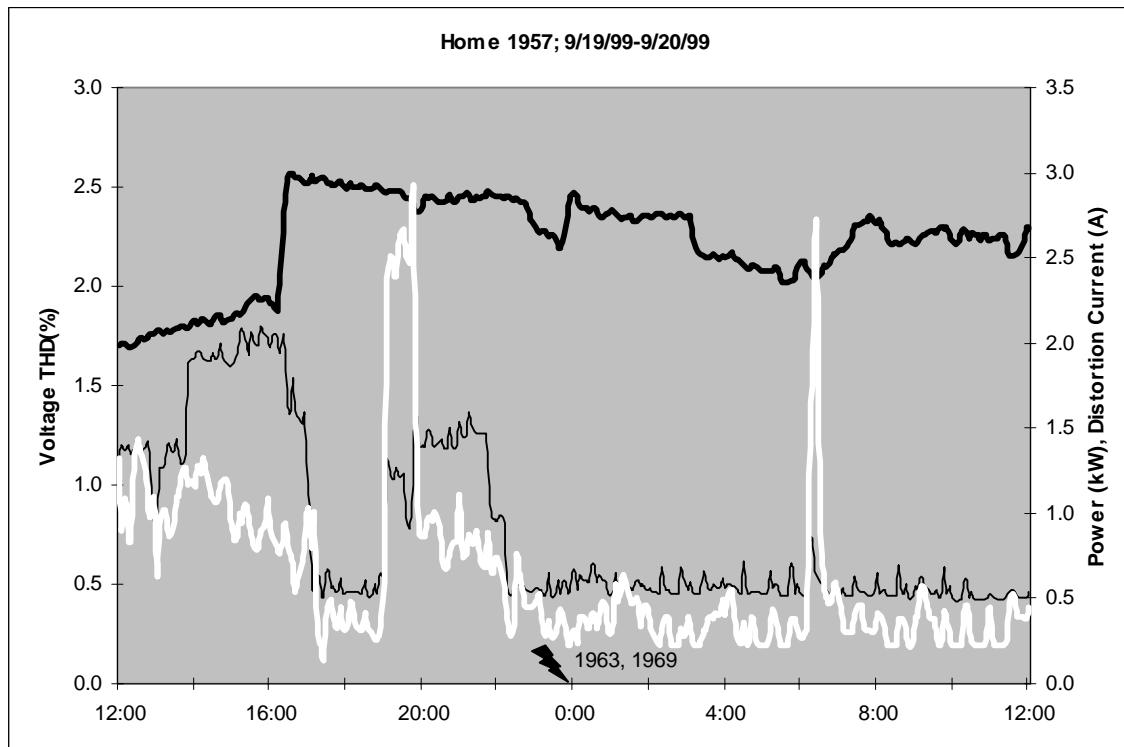


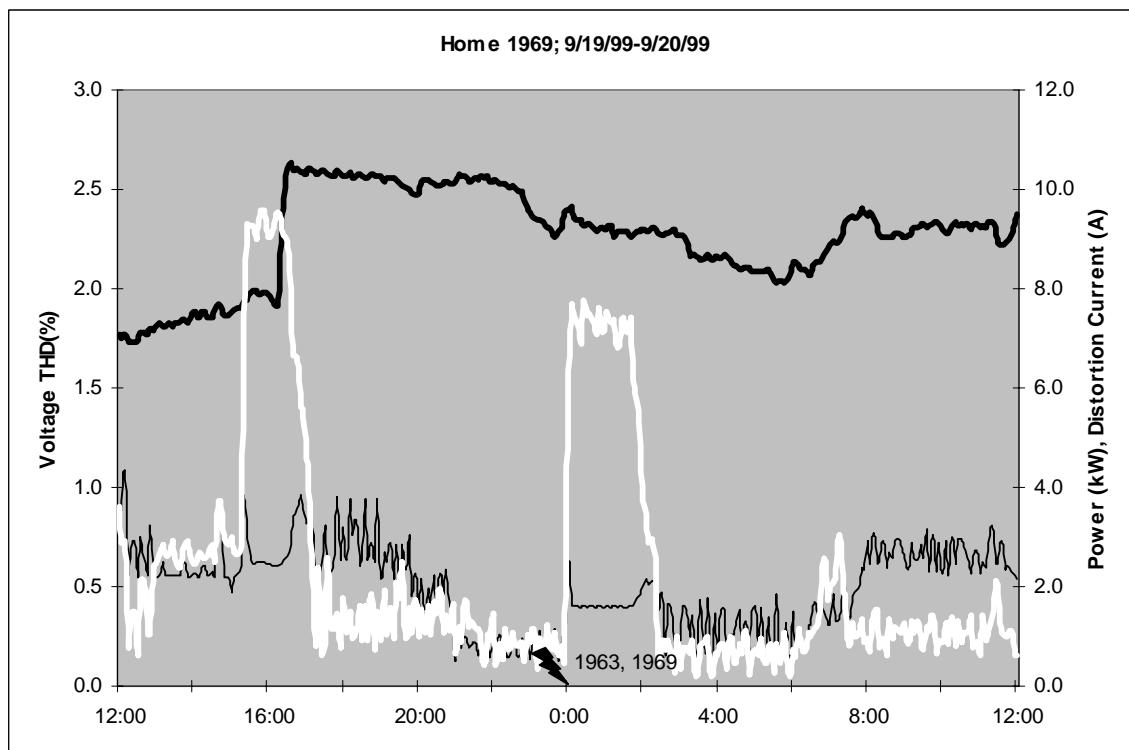
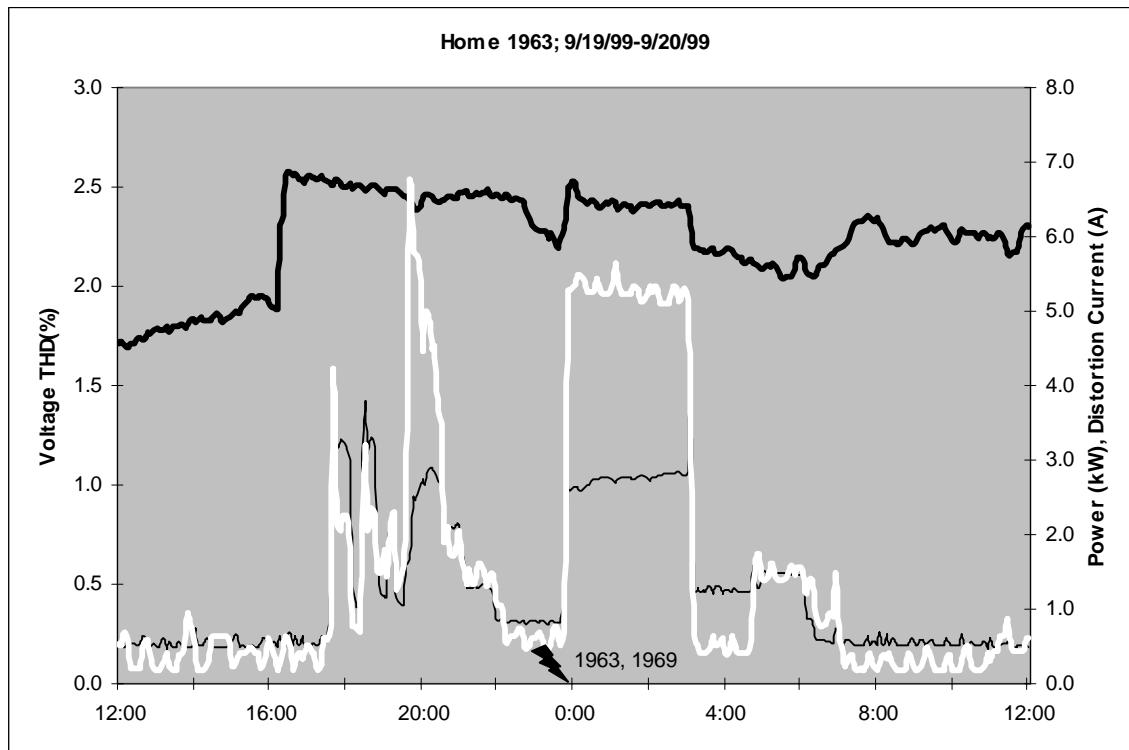




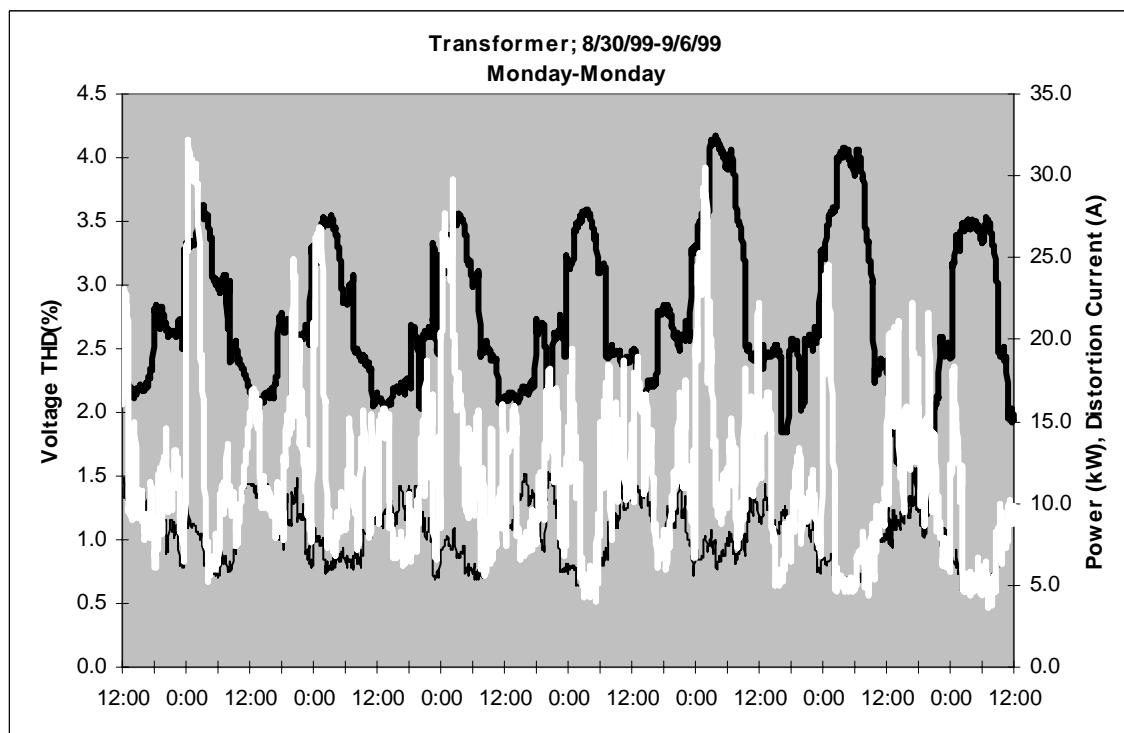
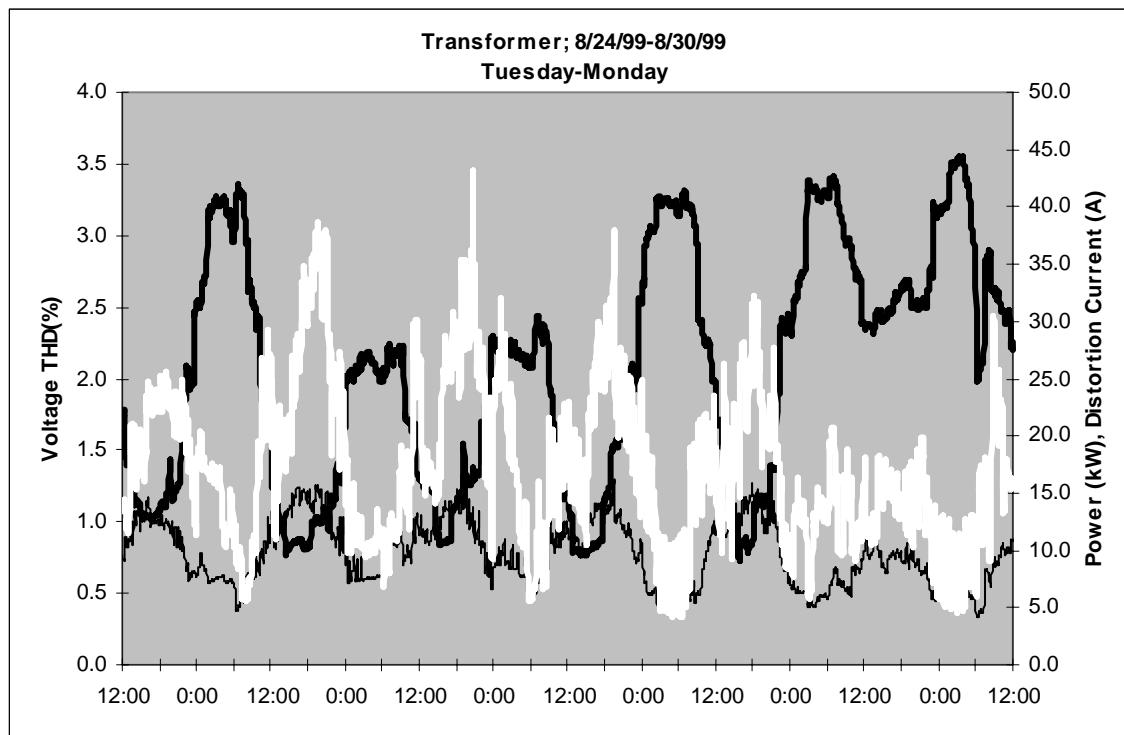


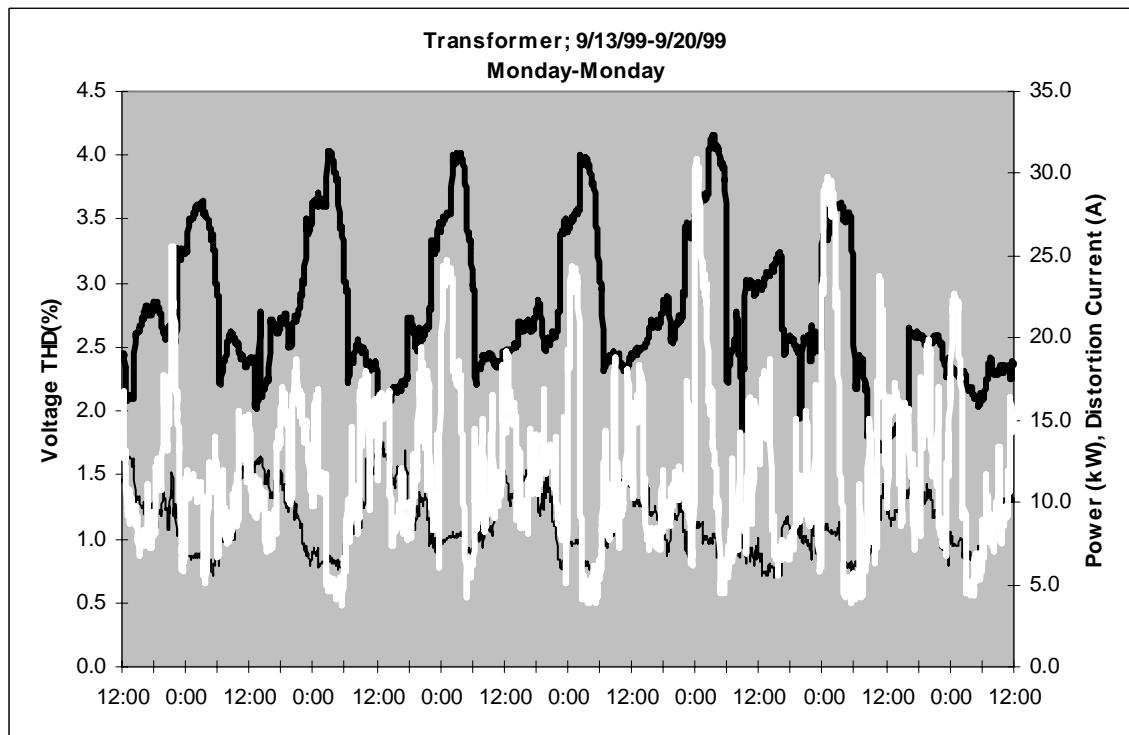
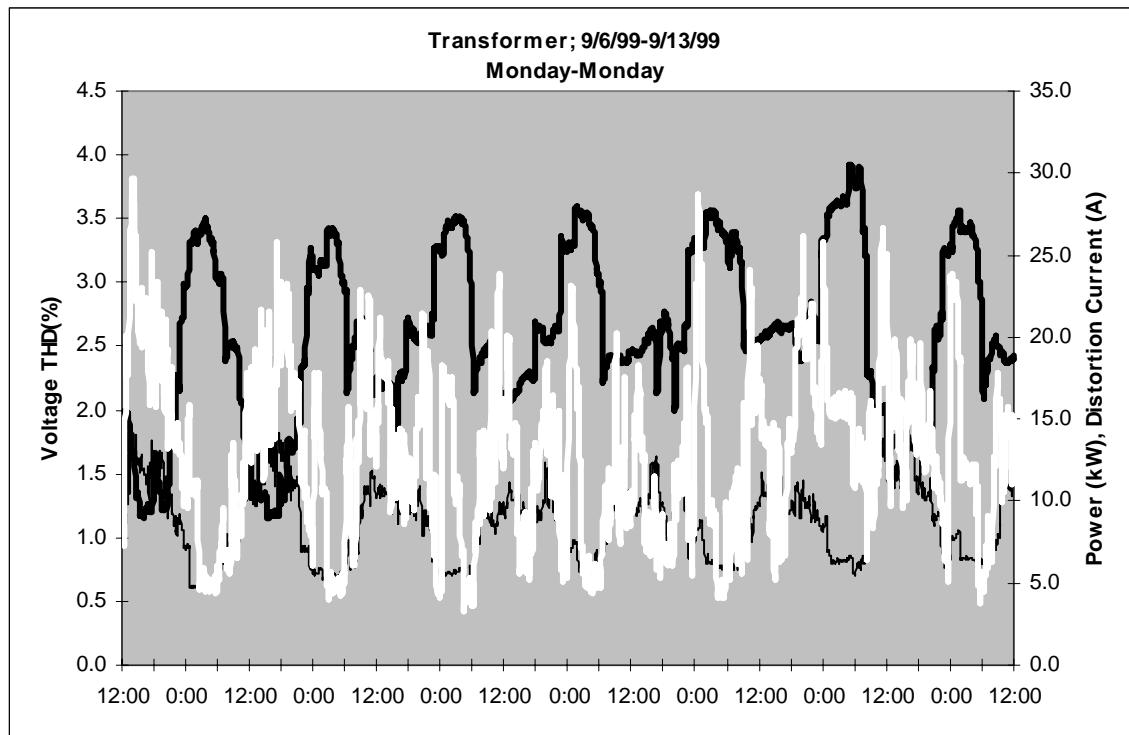






UTILITY B WEEKLY GRAPHS







Appendix D.2

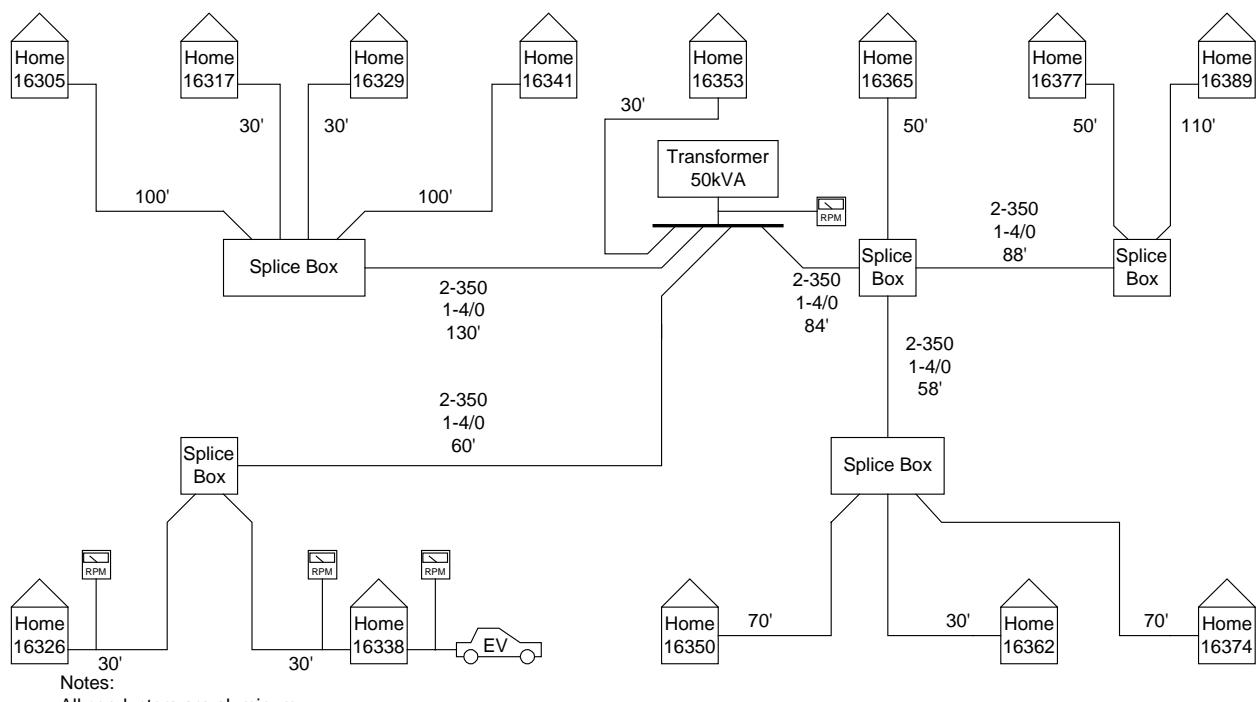
Utility E Data



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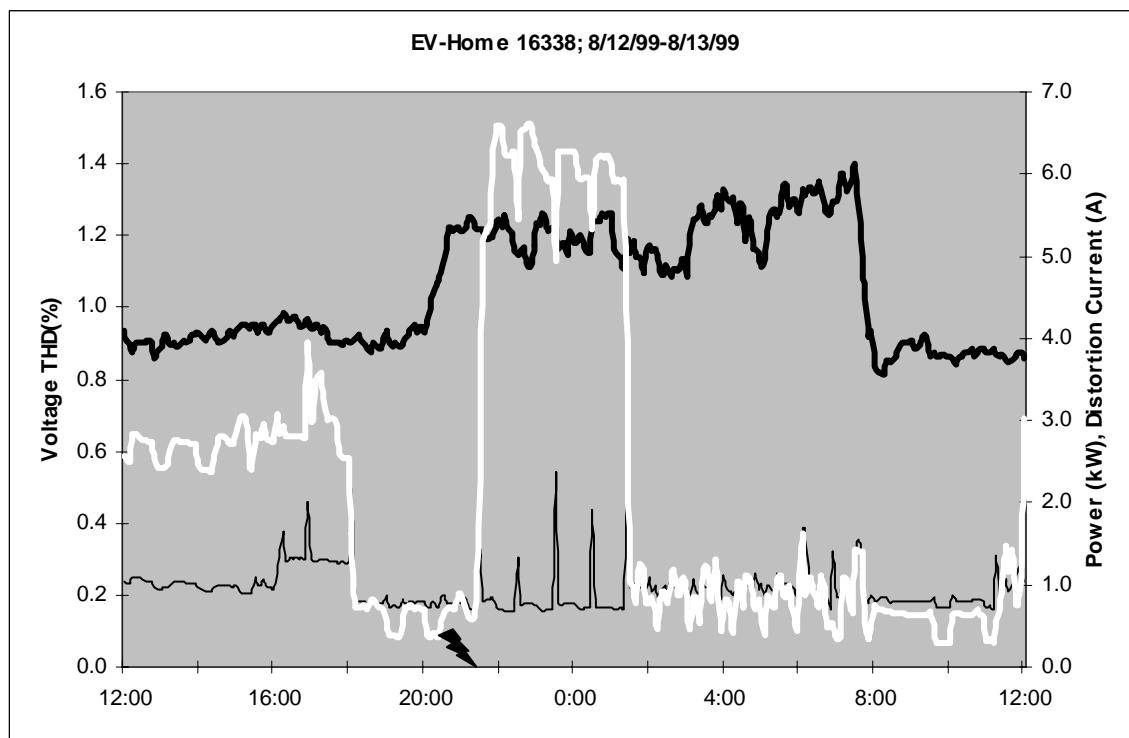
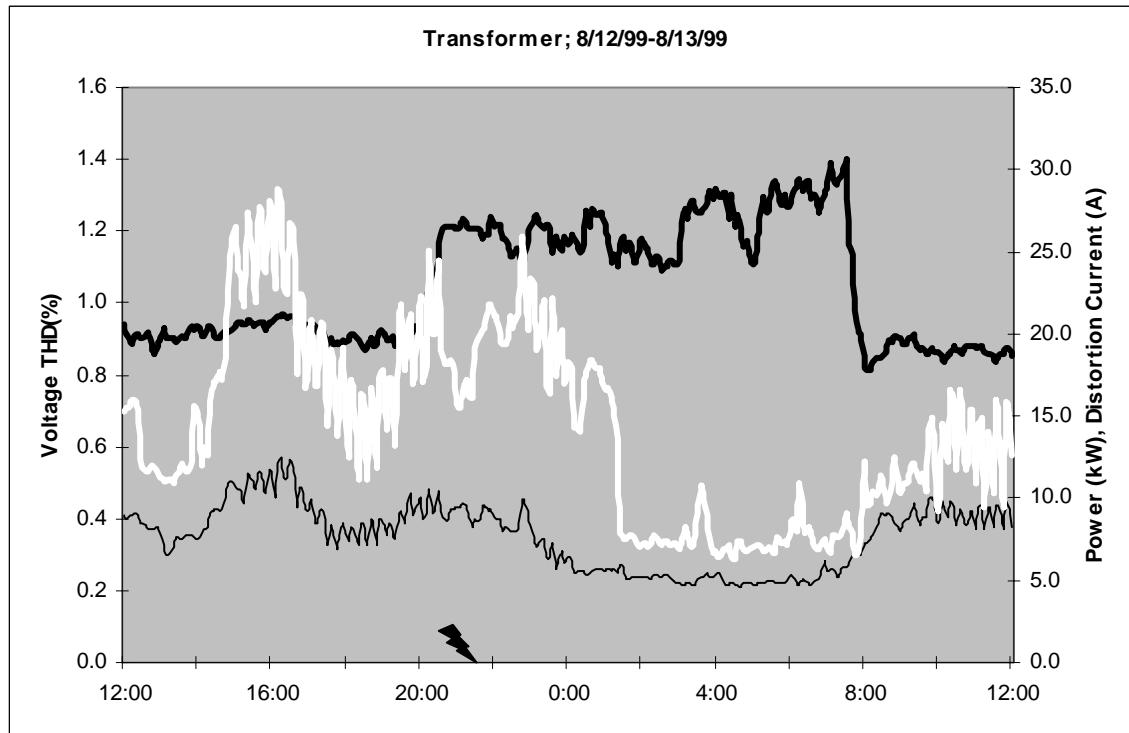
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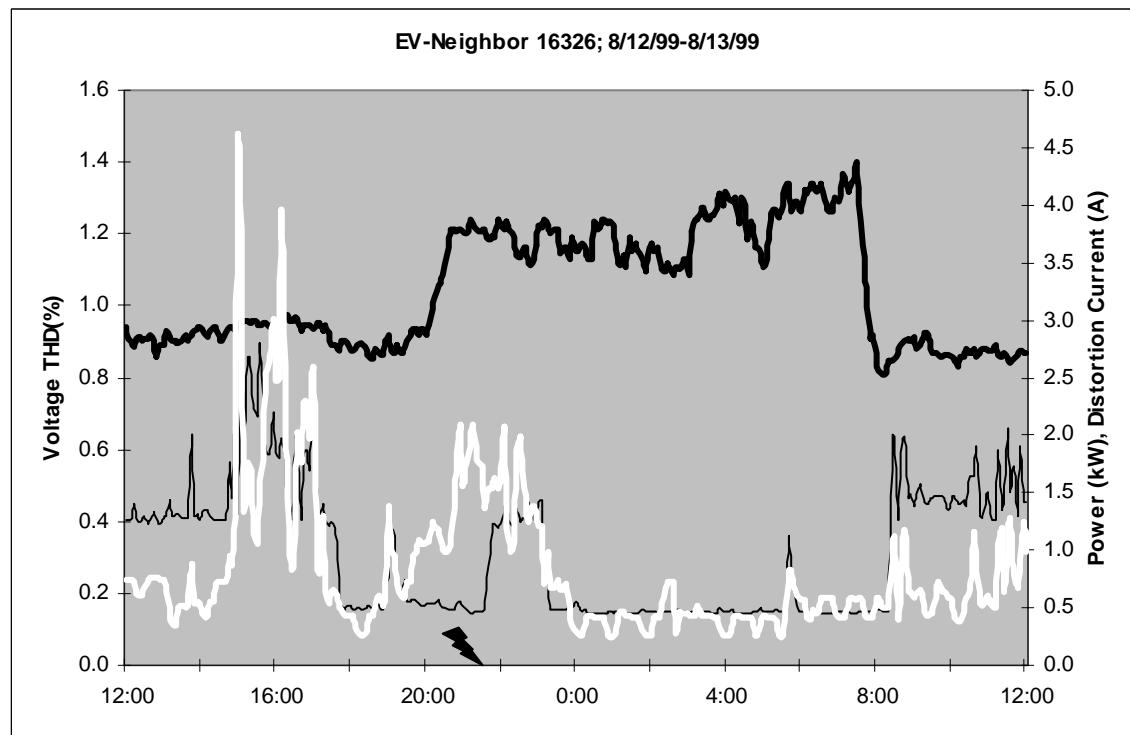
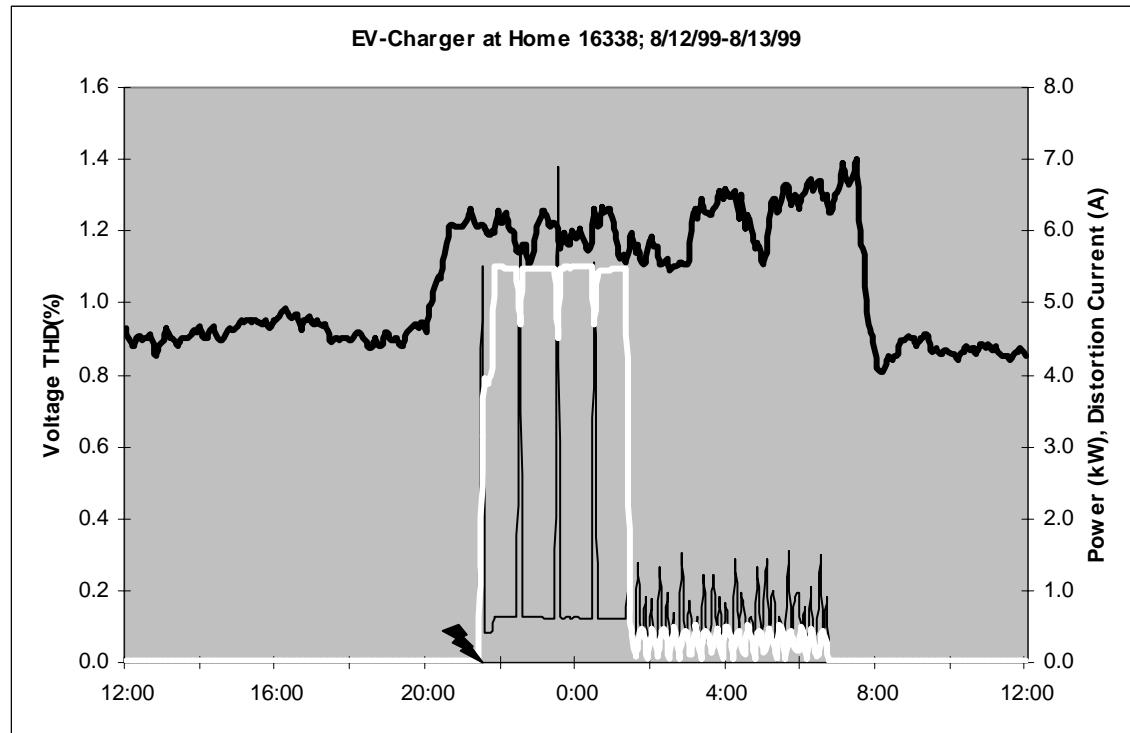


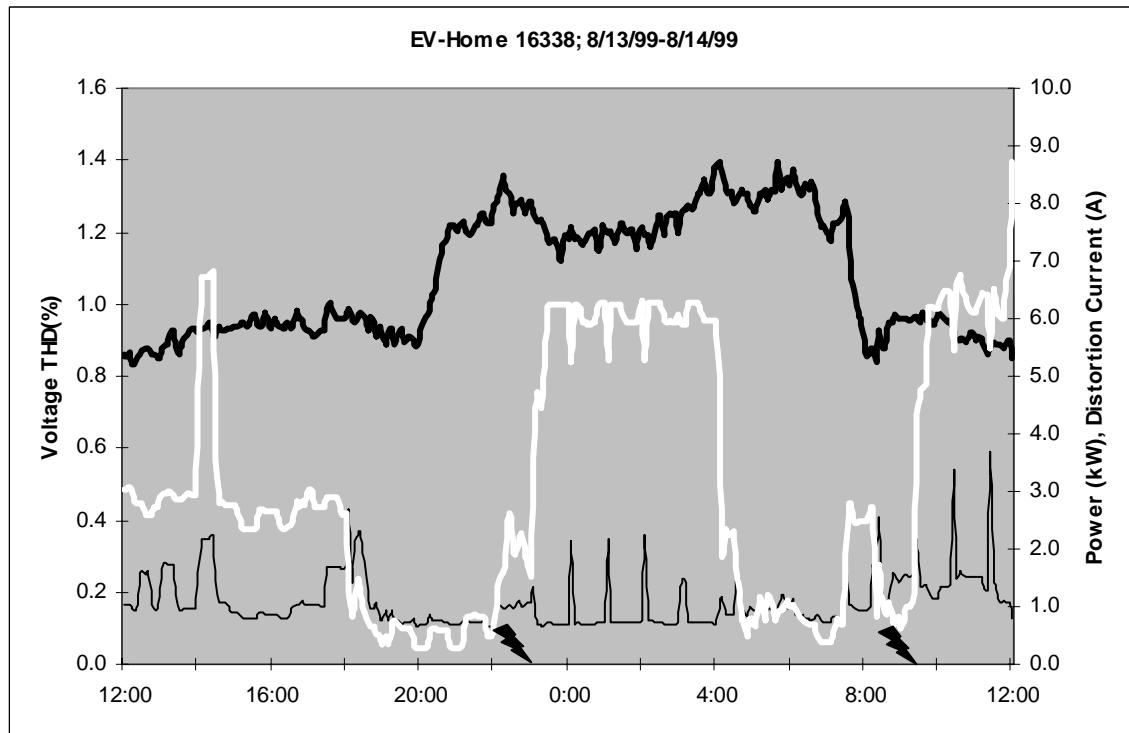
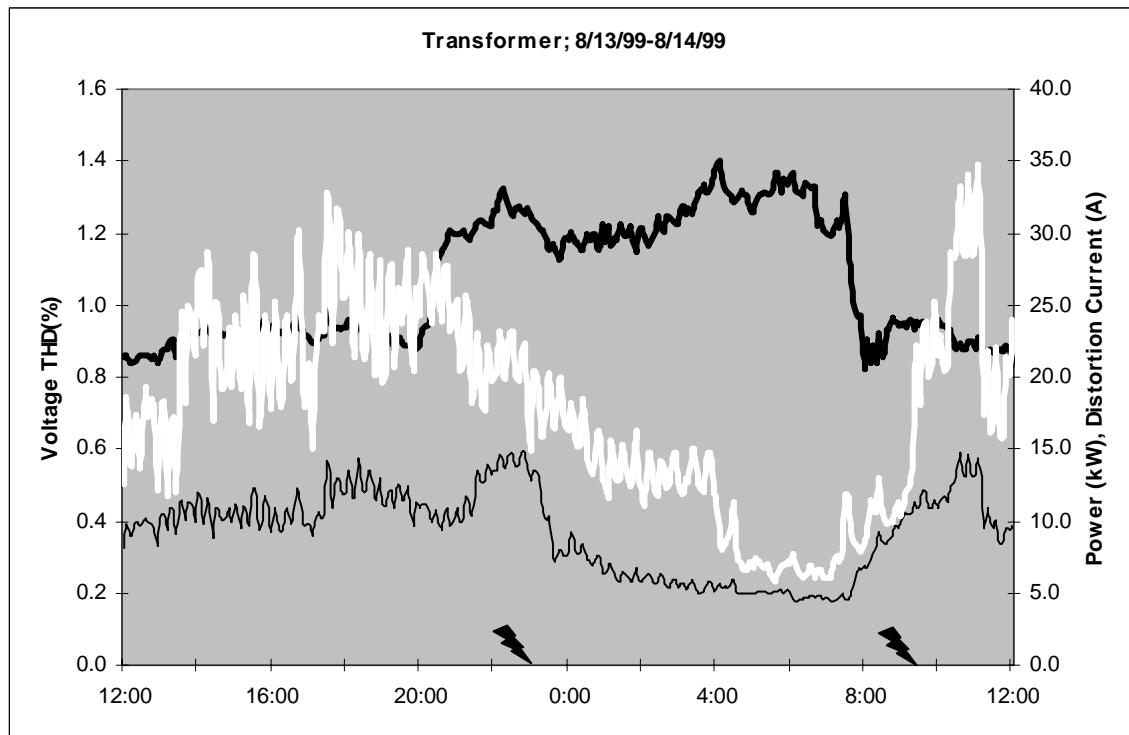
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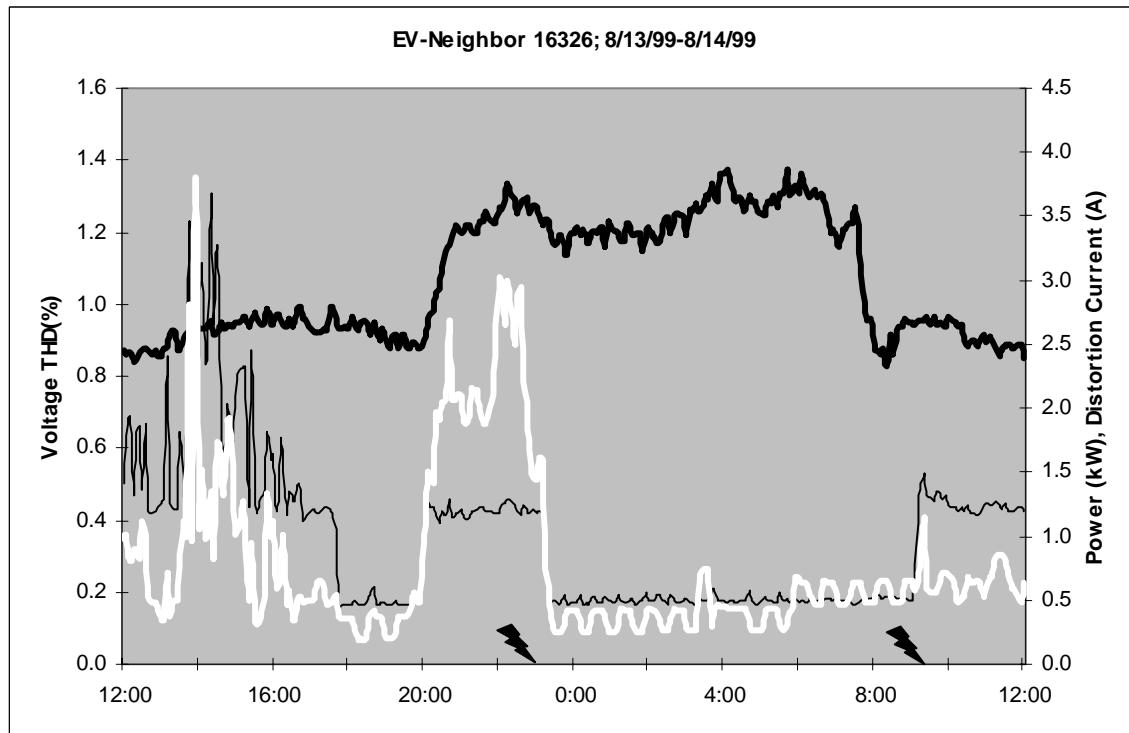
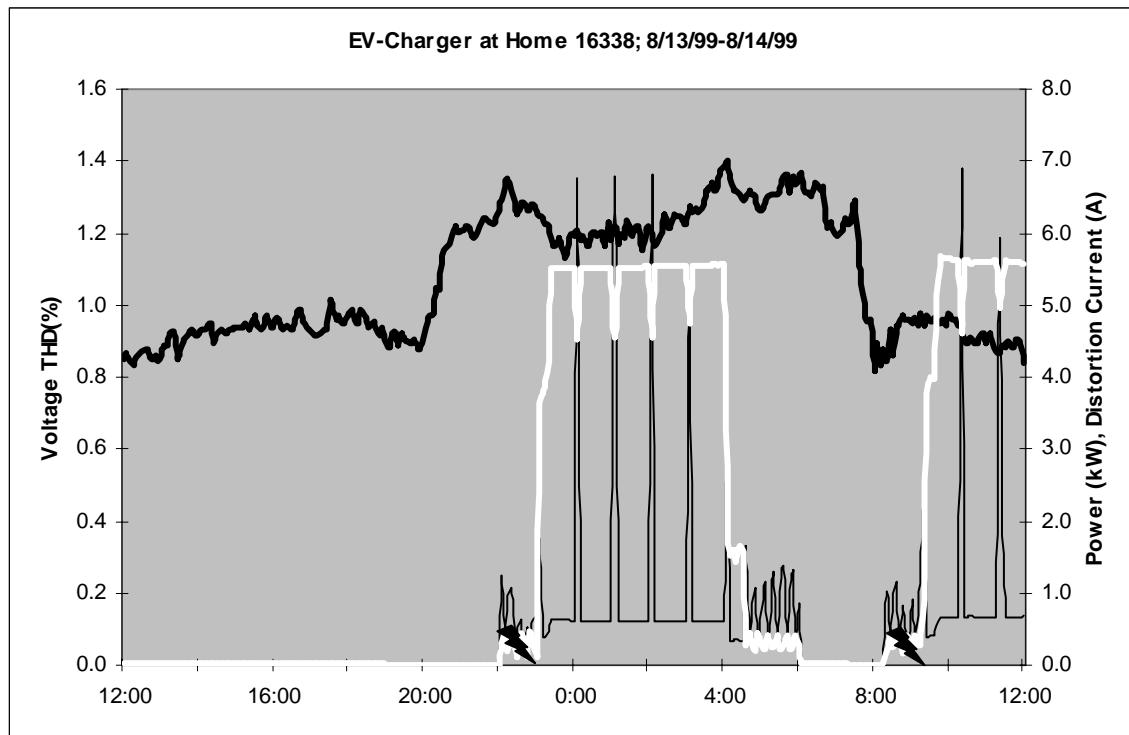


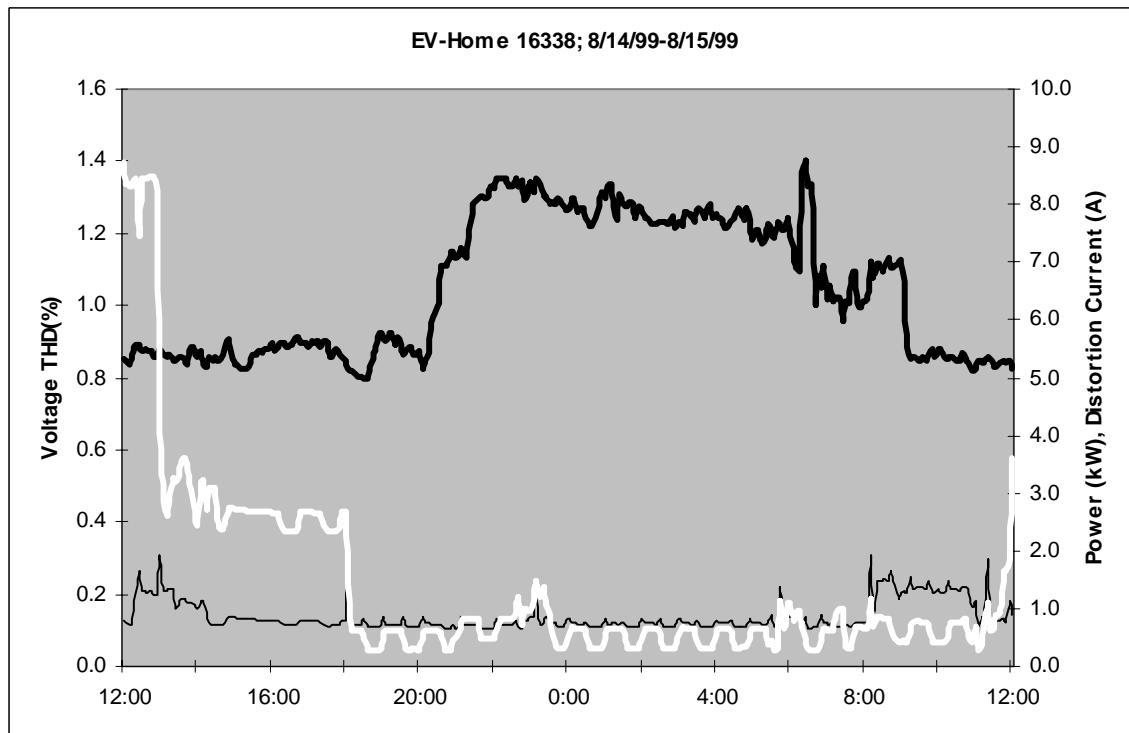
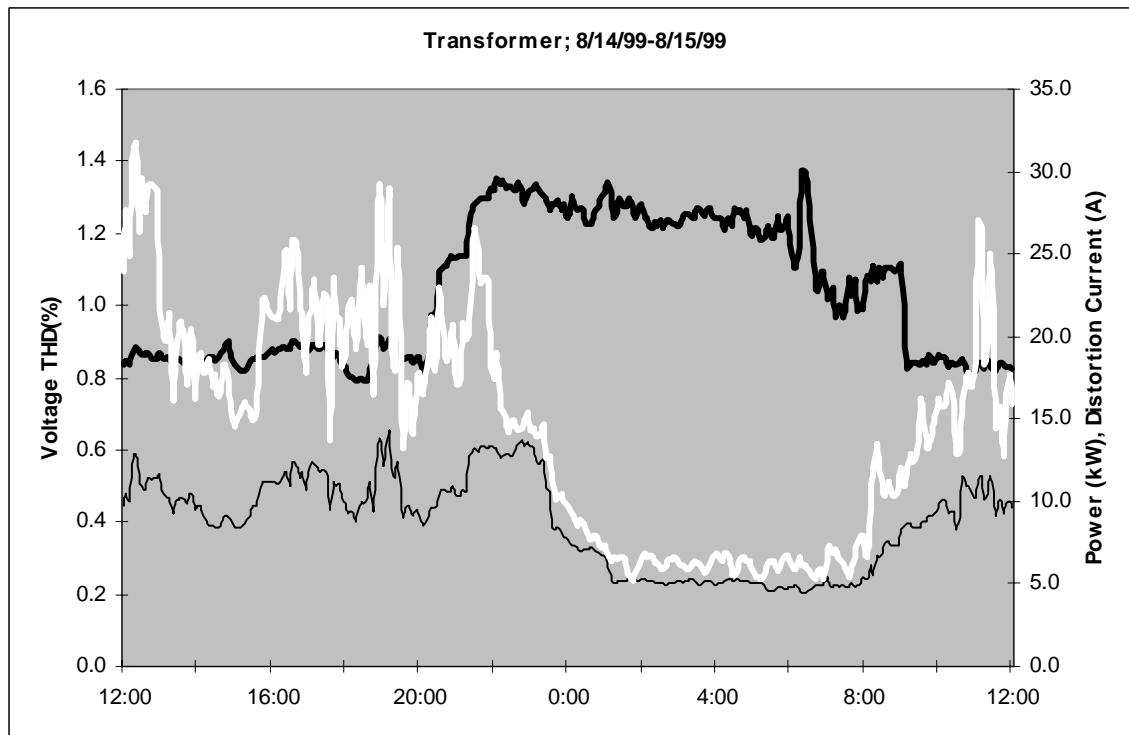
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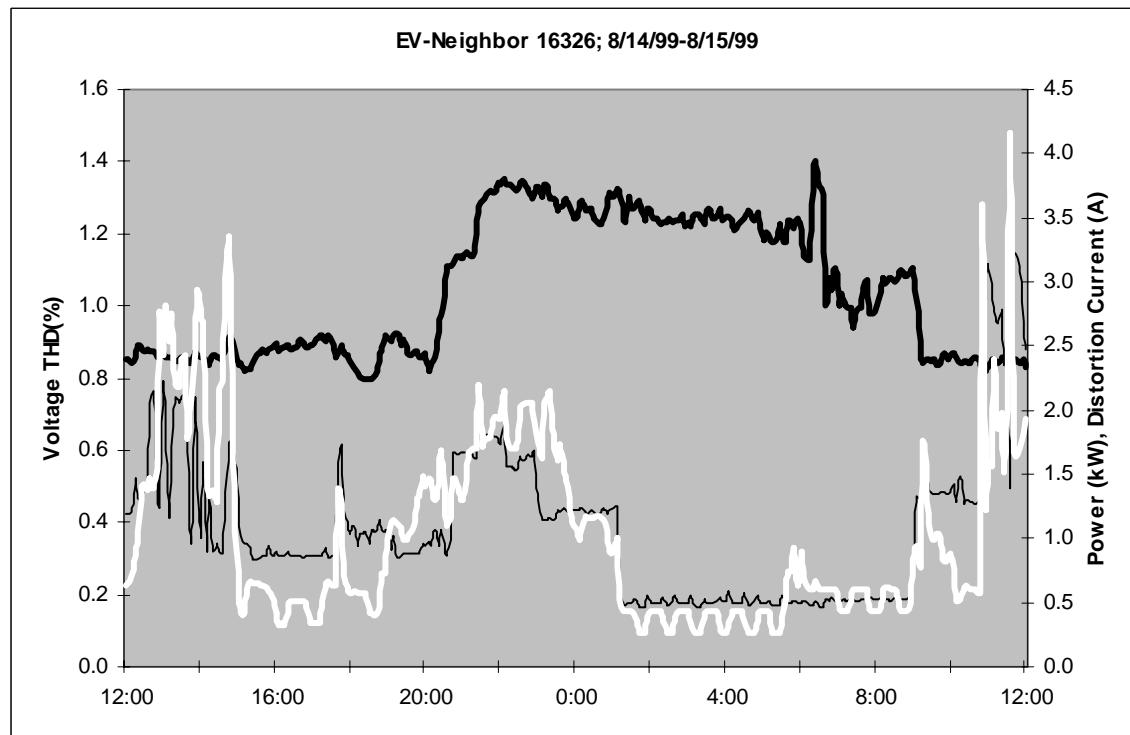
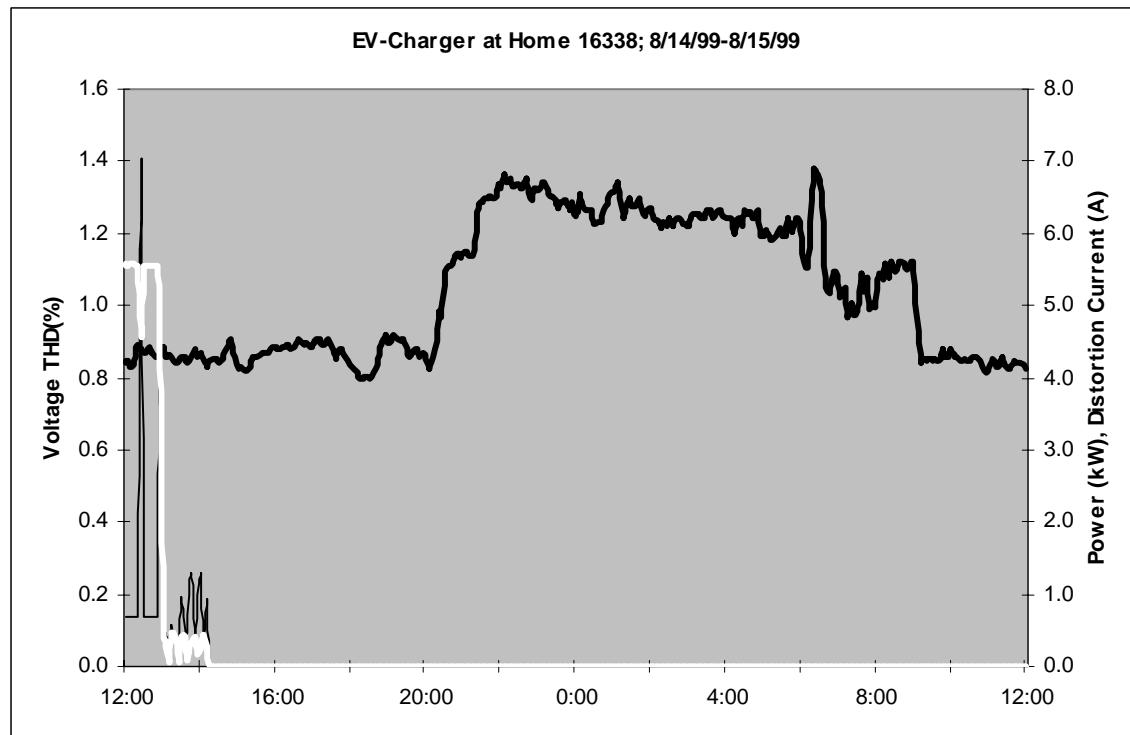


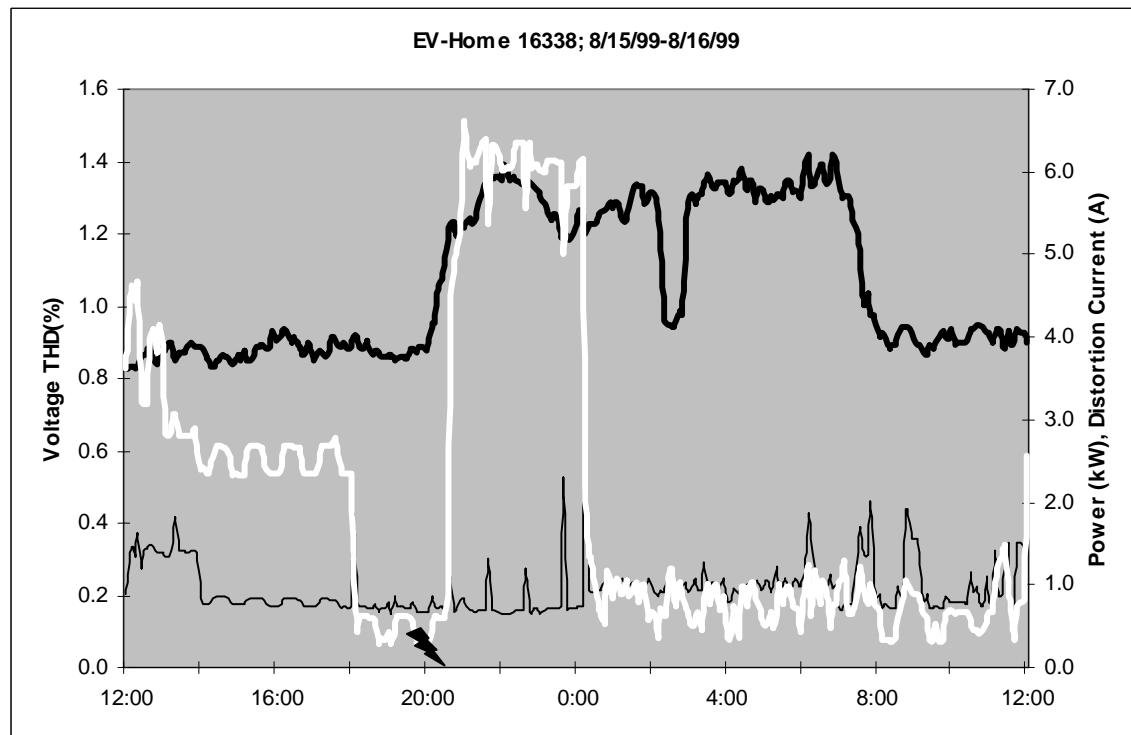
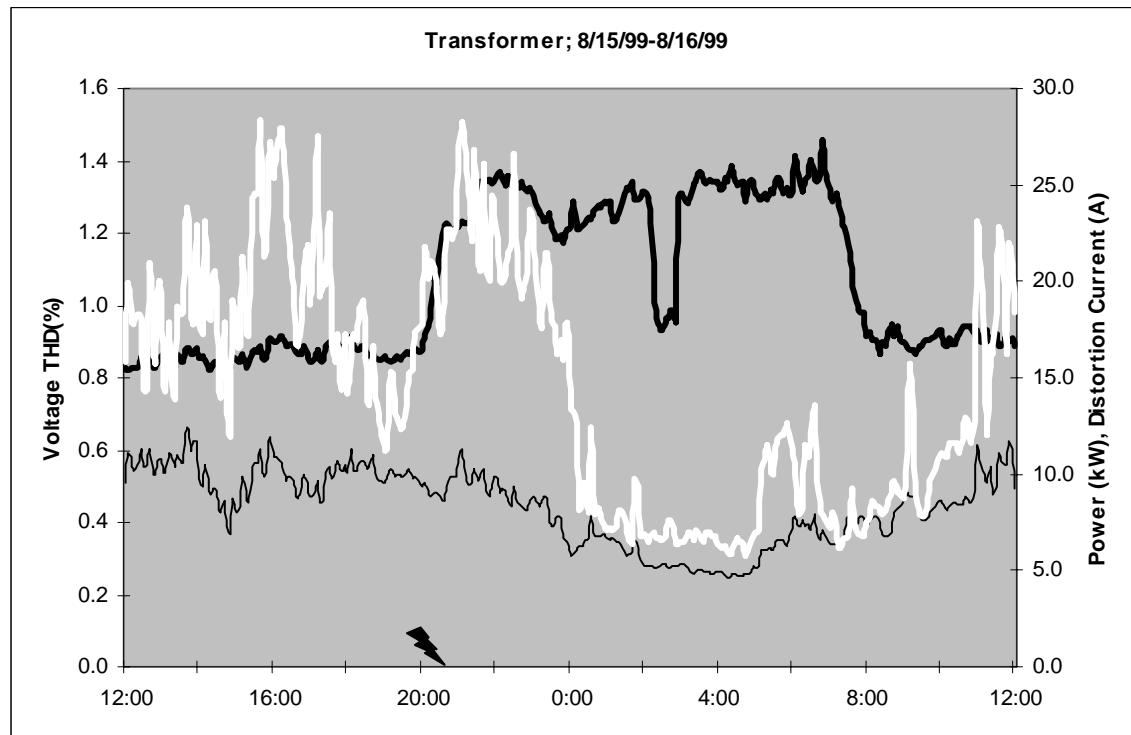


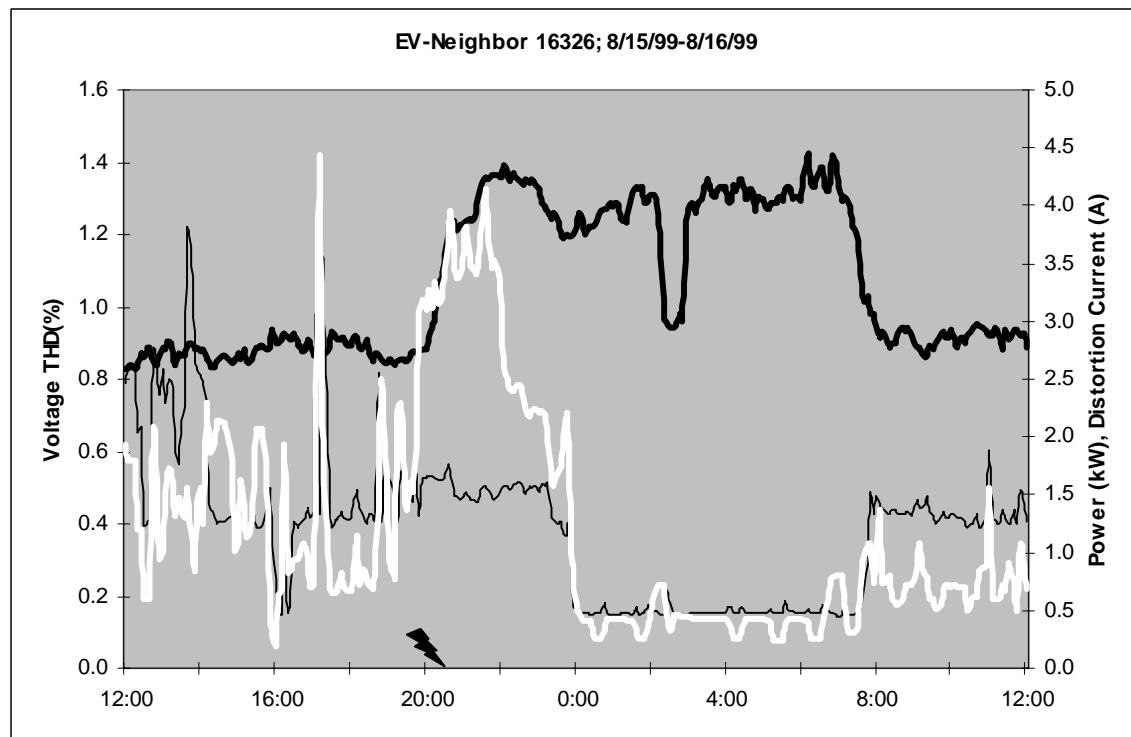
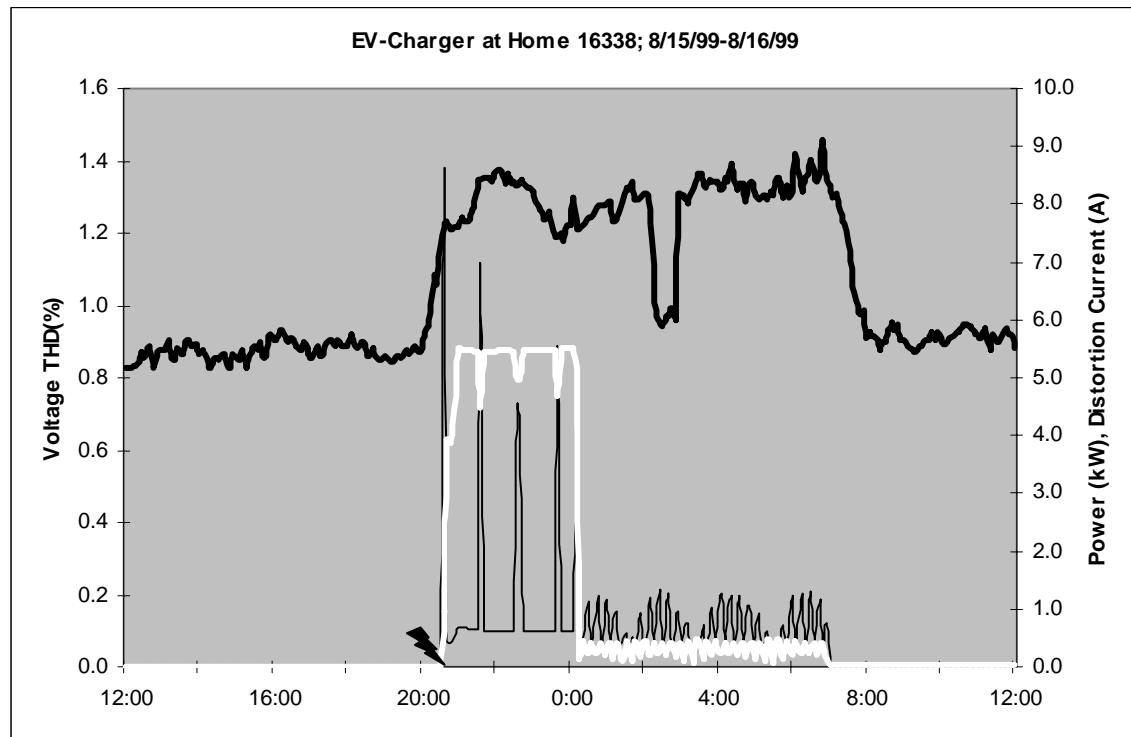


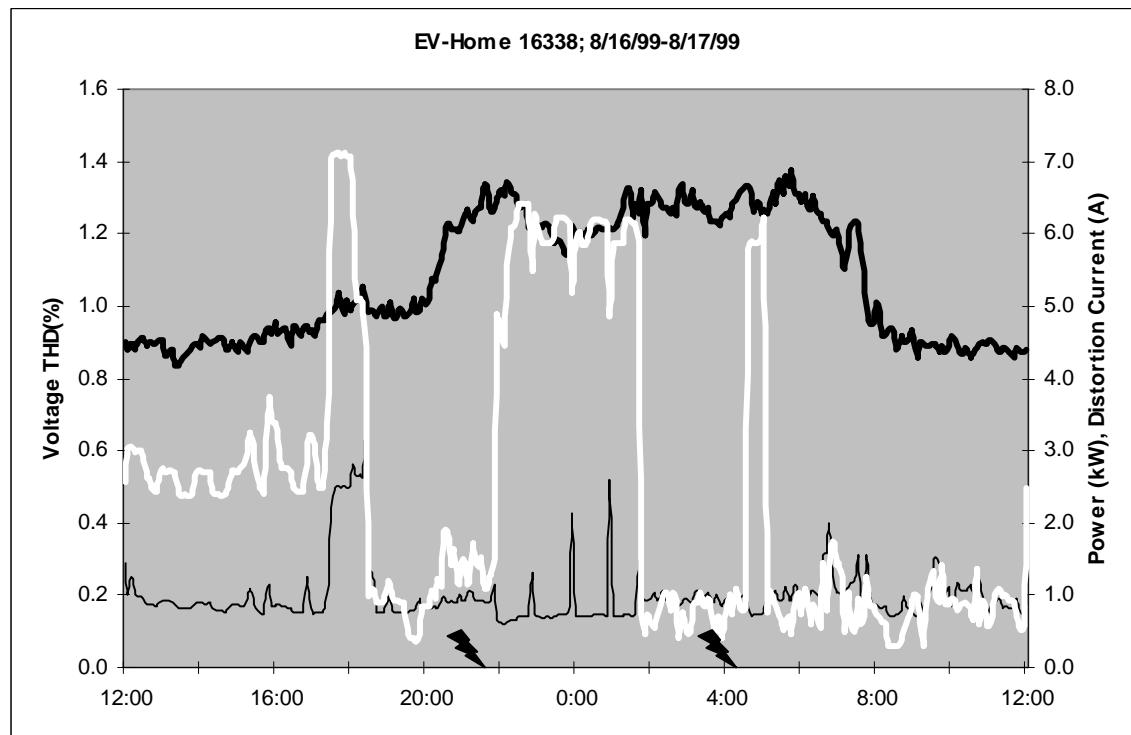
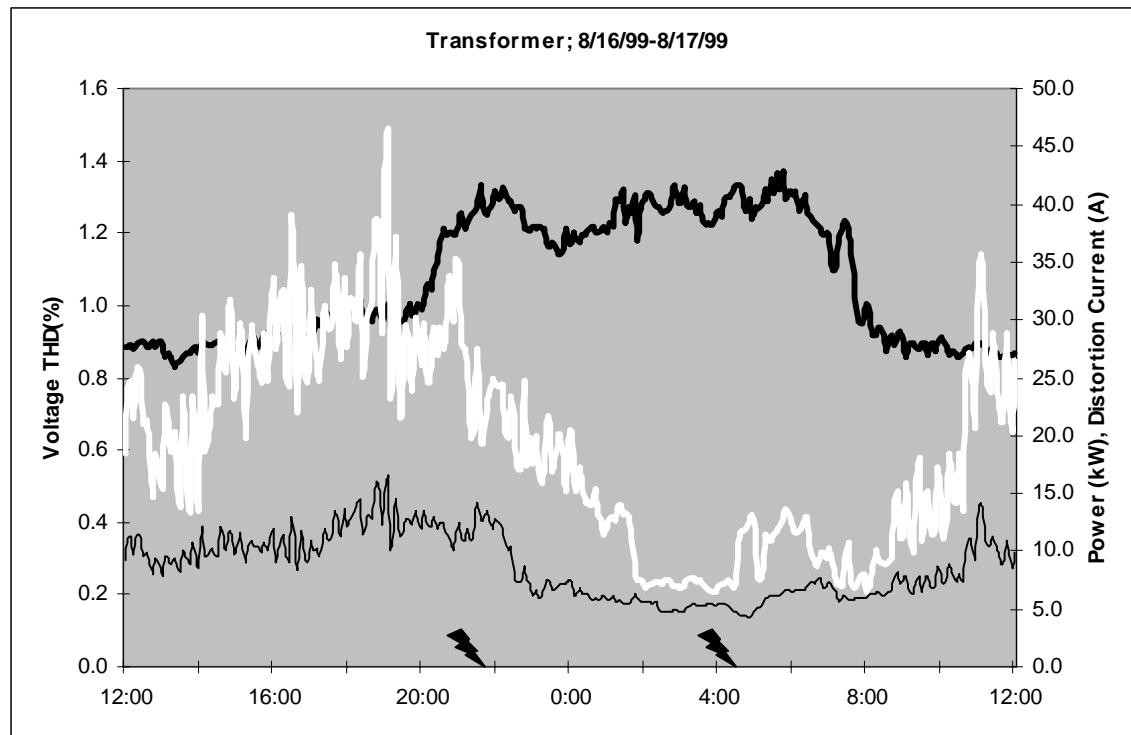


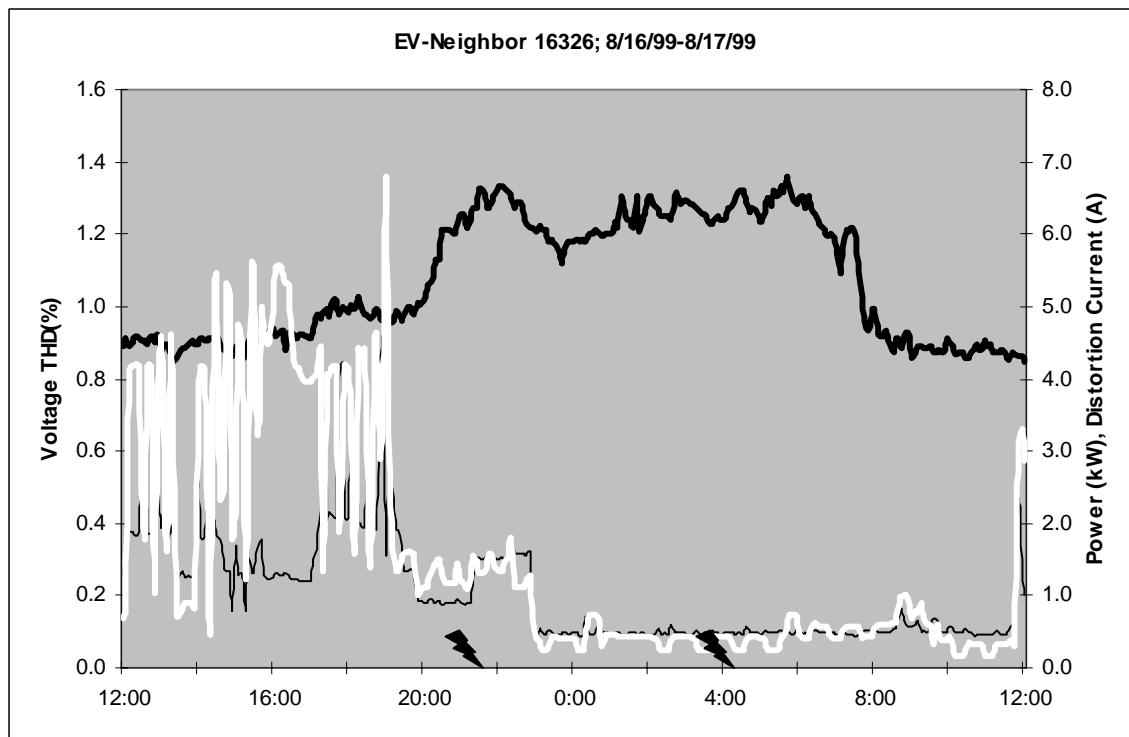
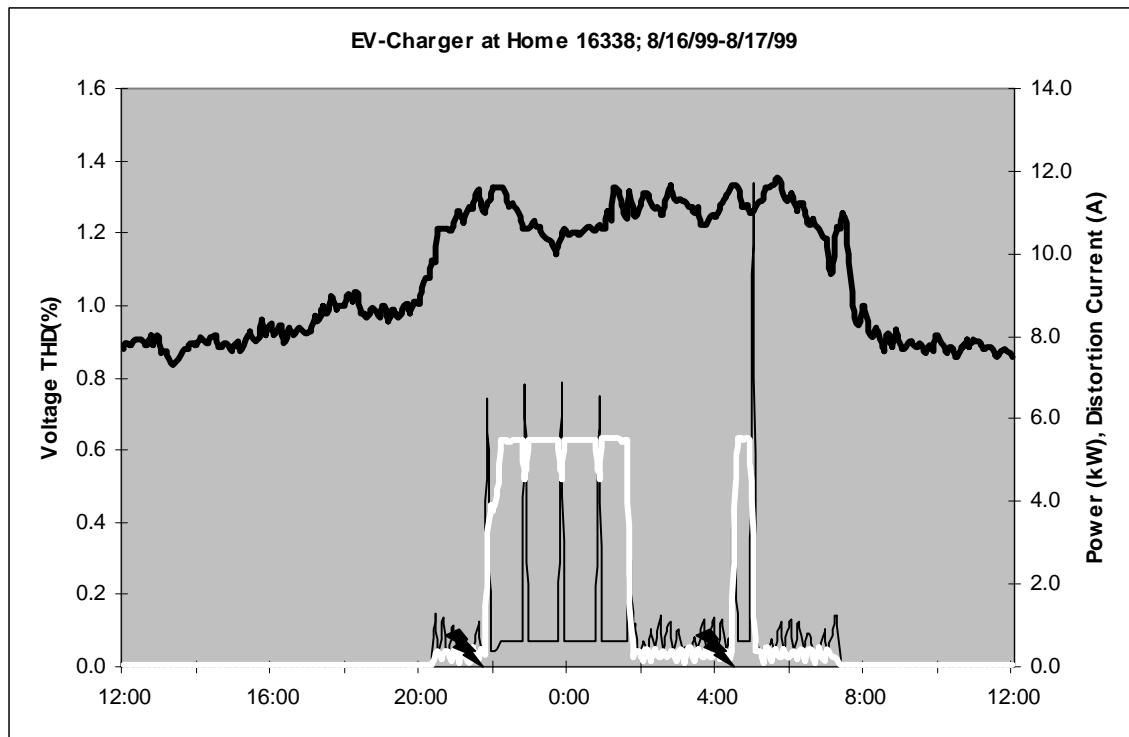


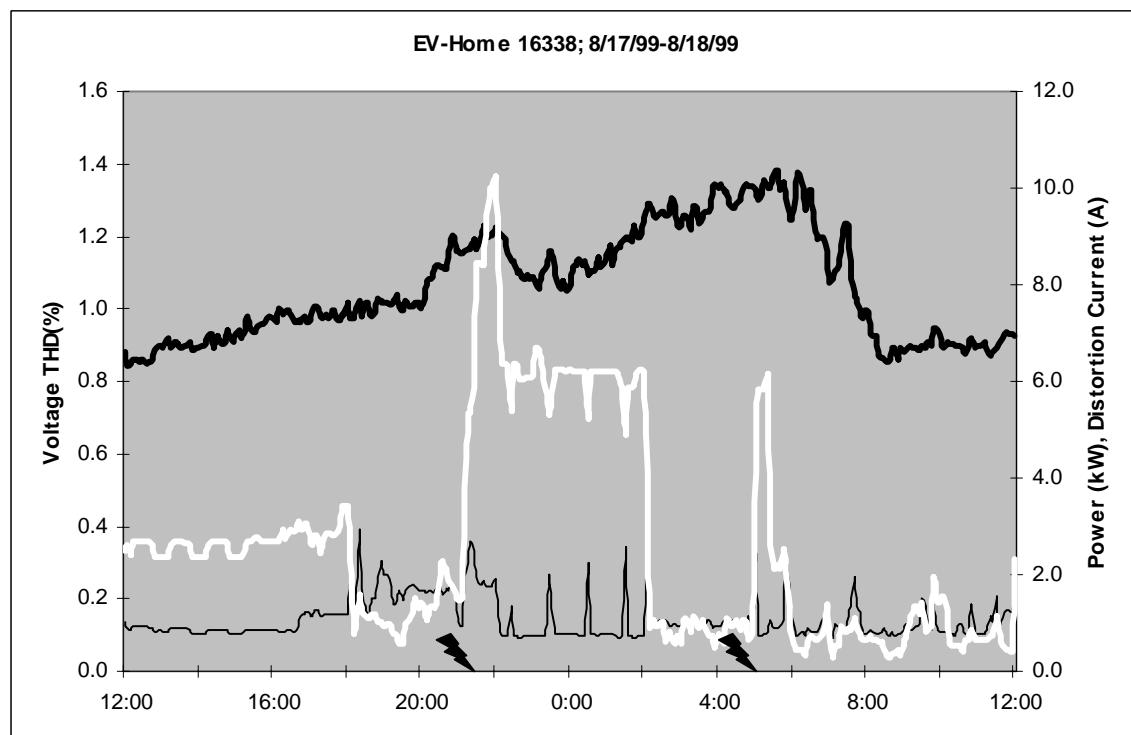
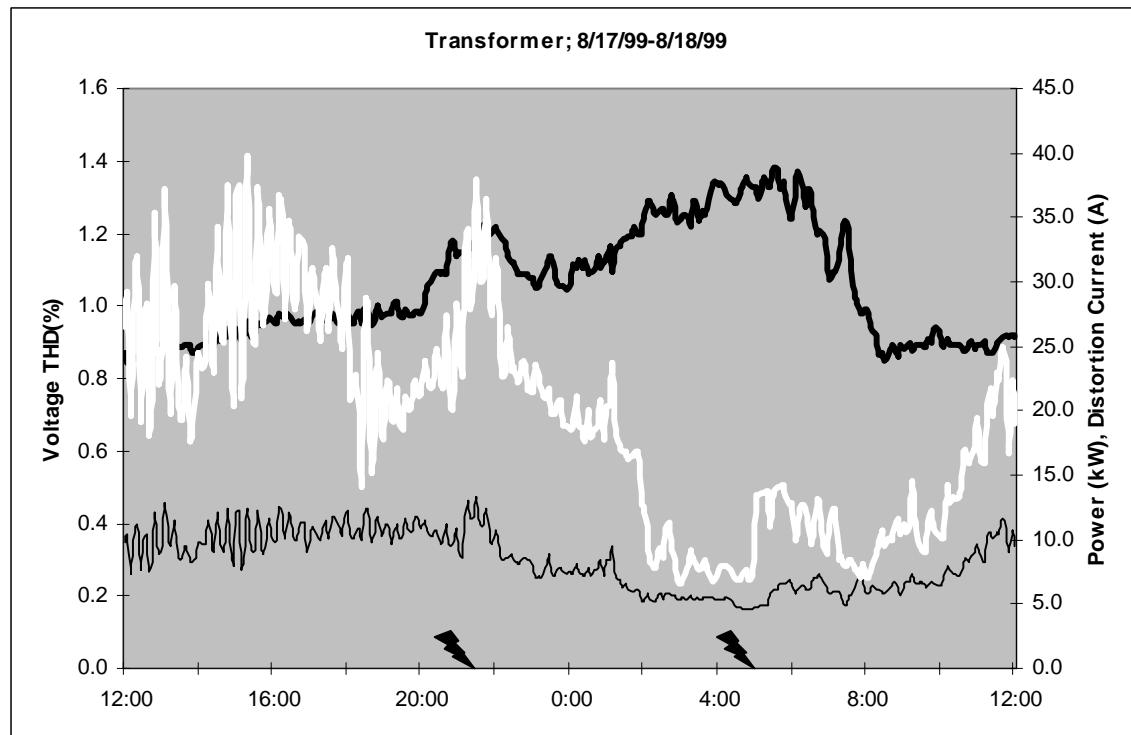


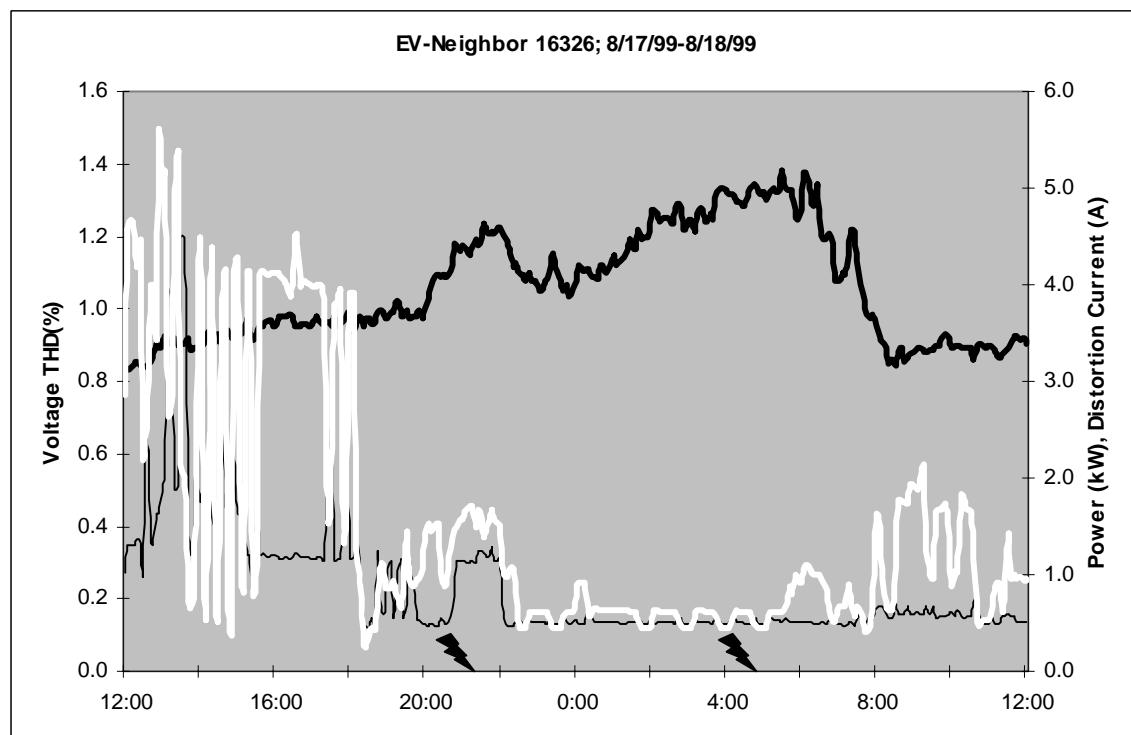
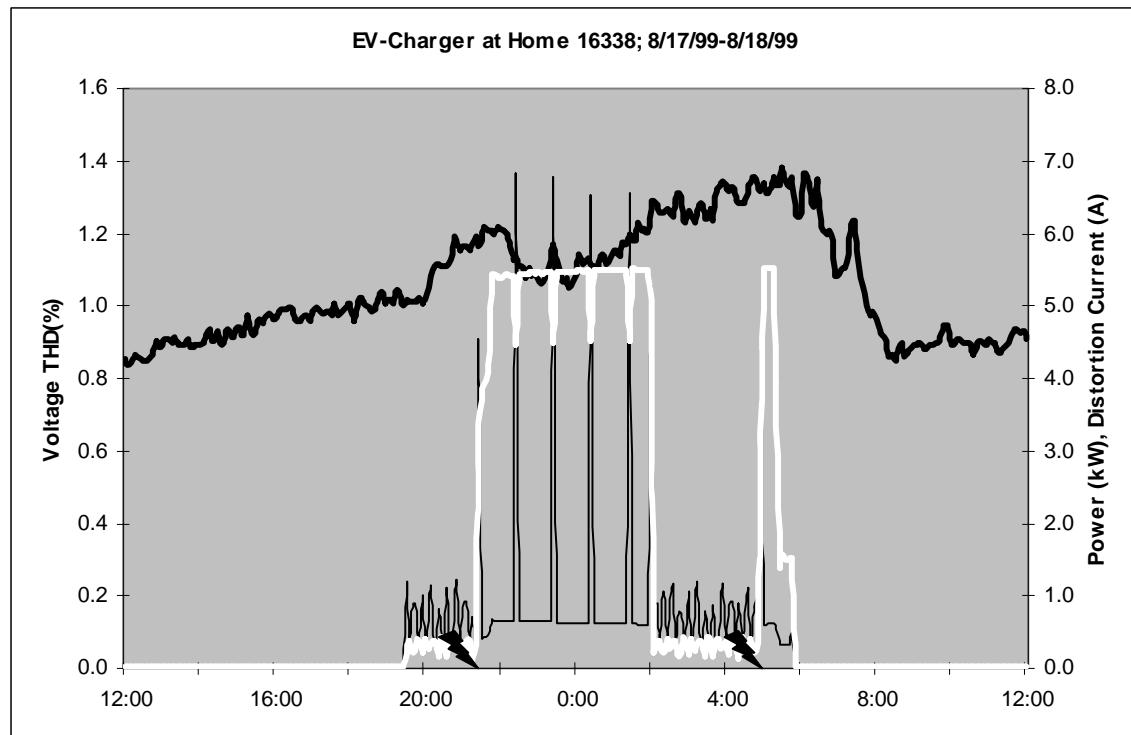


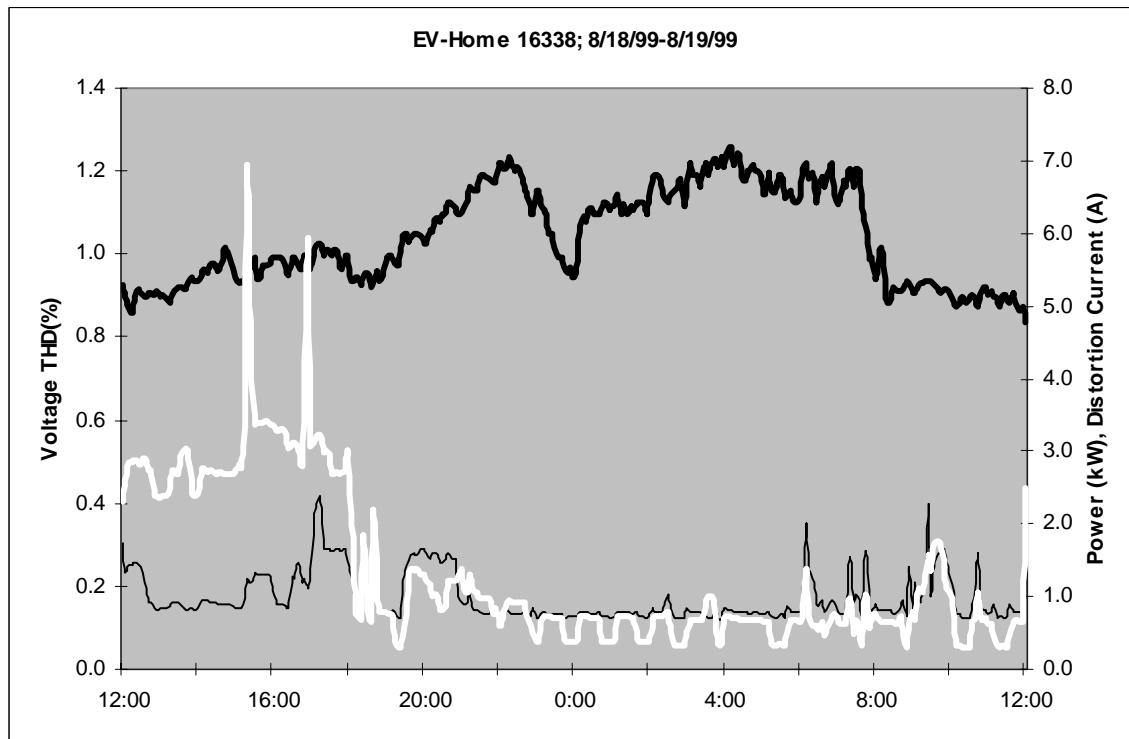
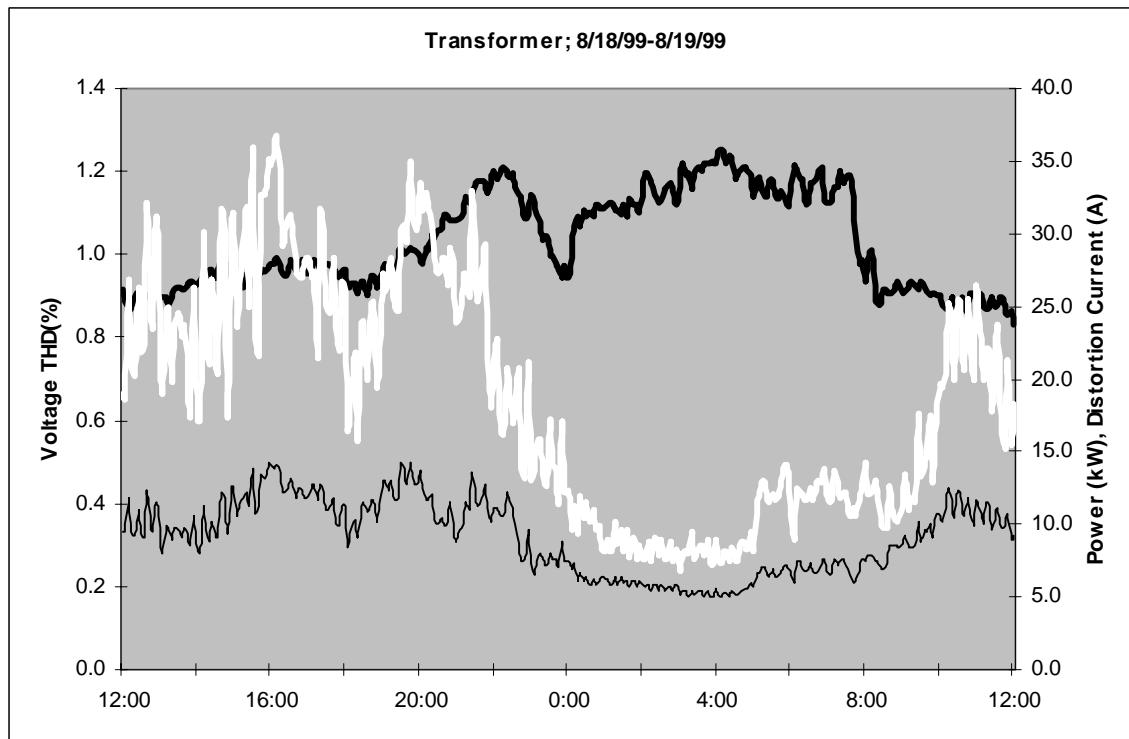


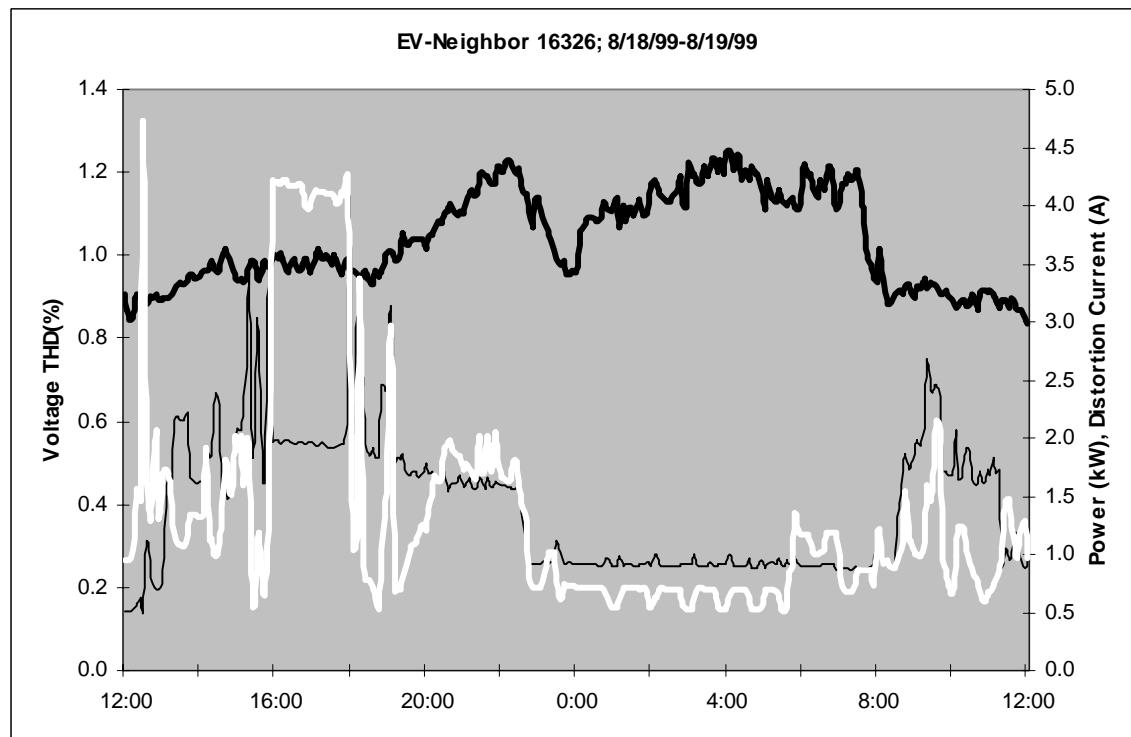
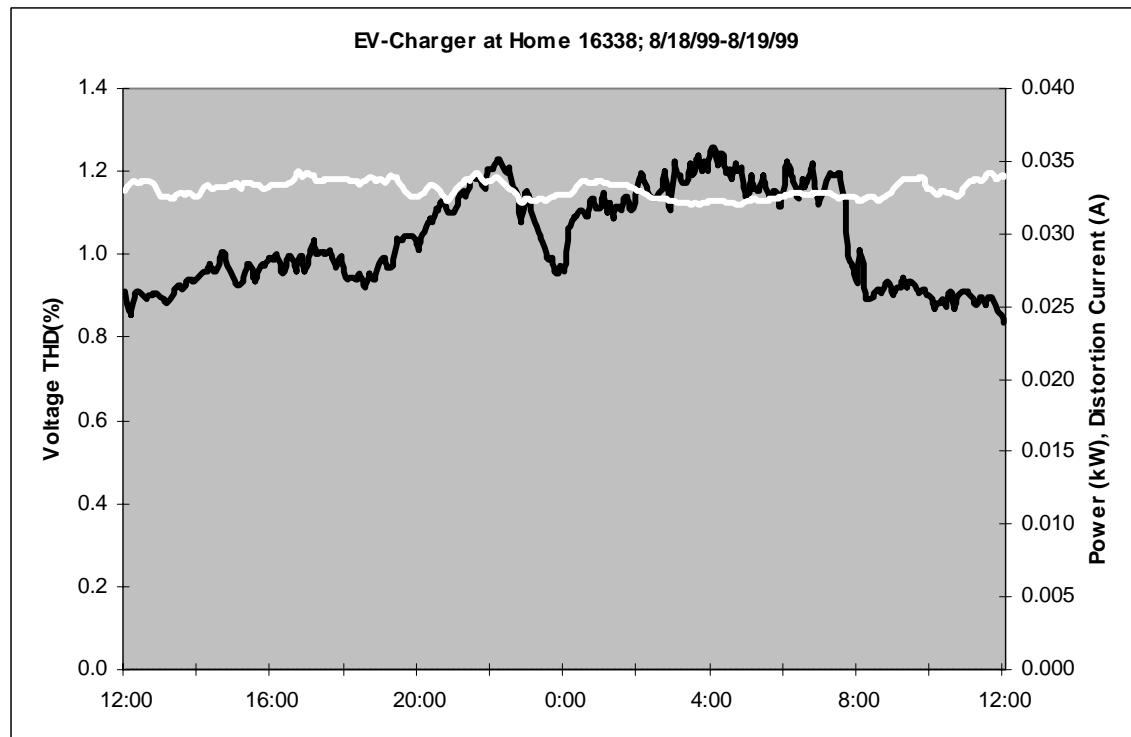


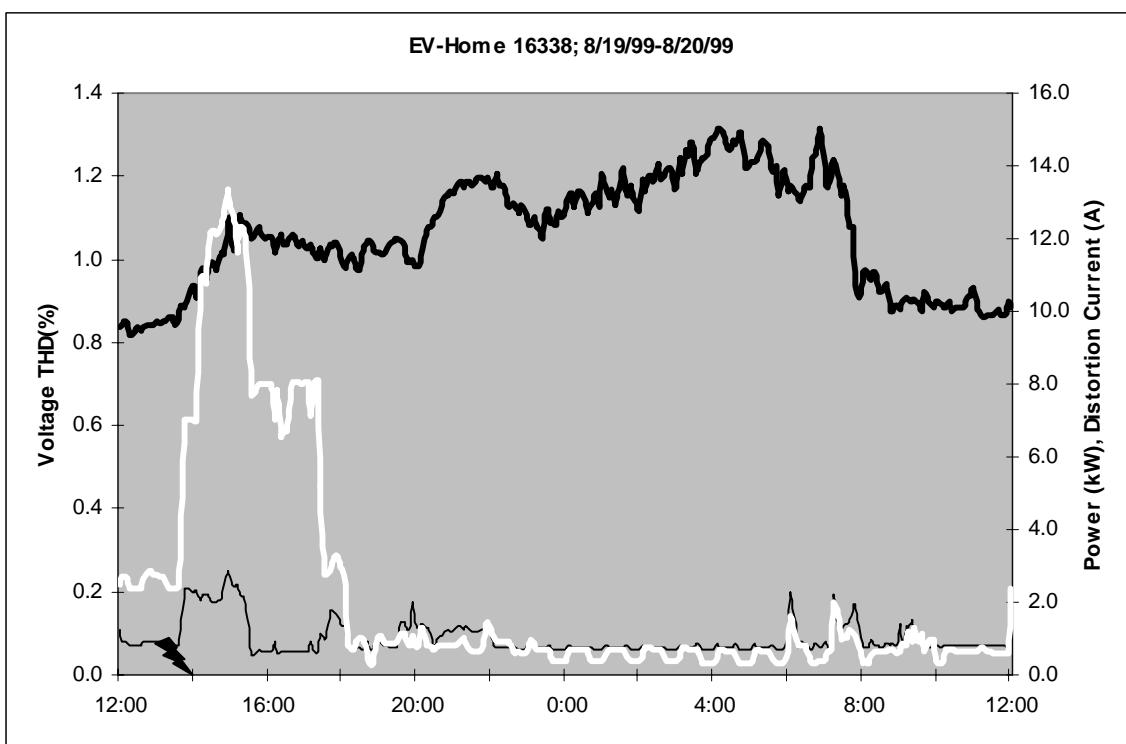
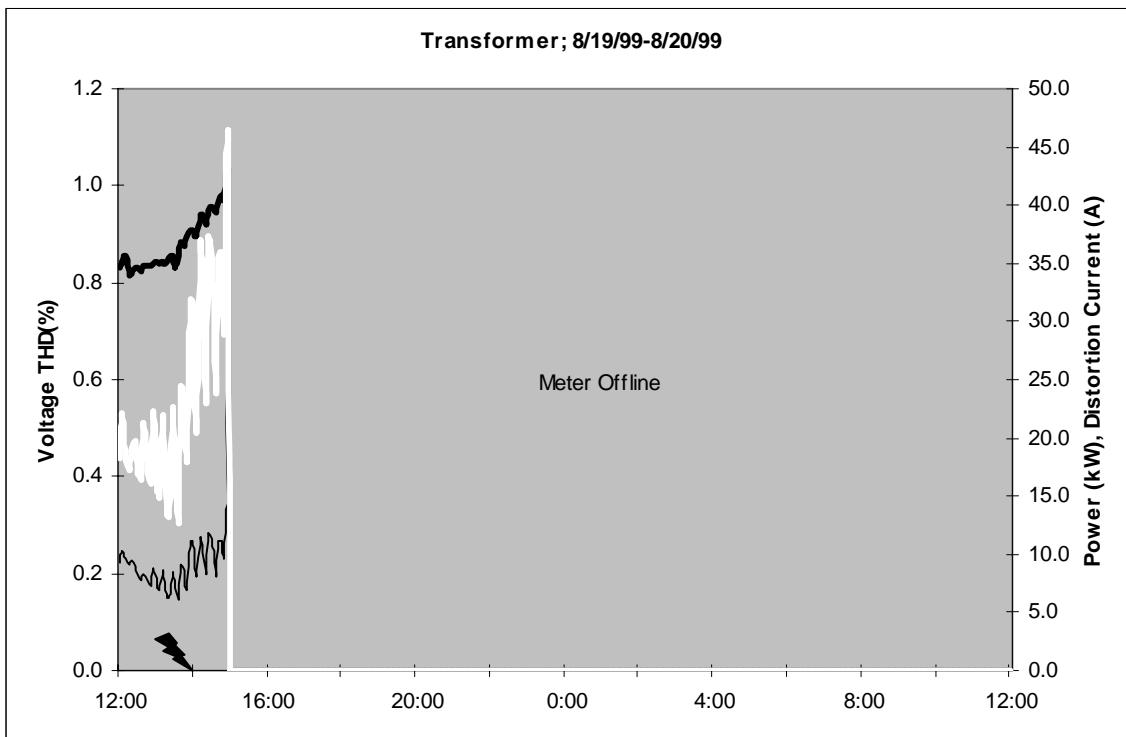


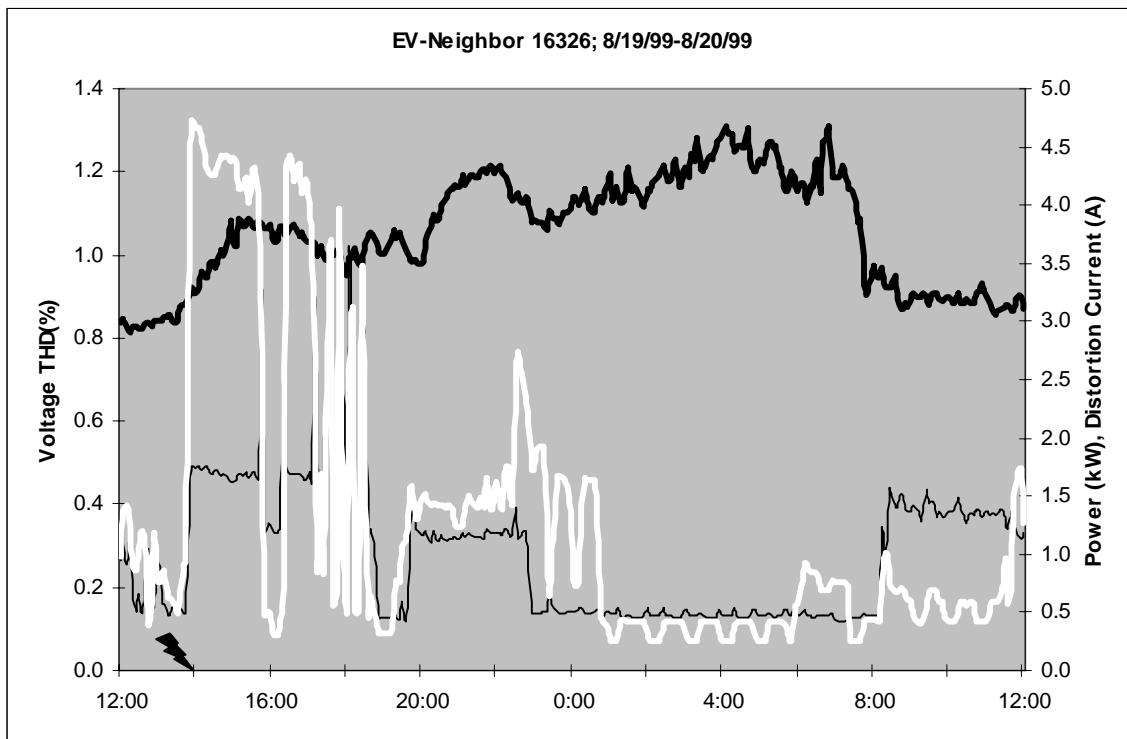
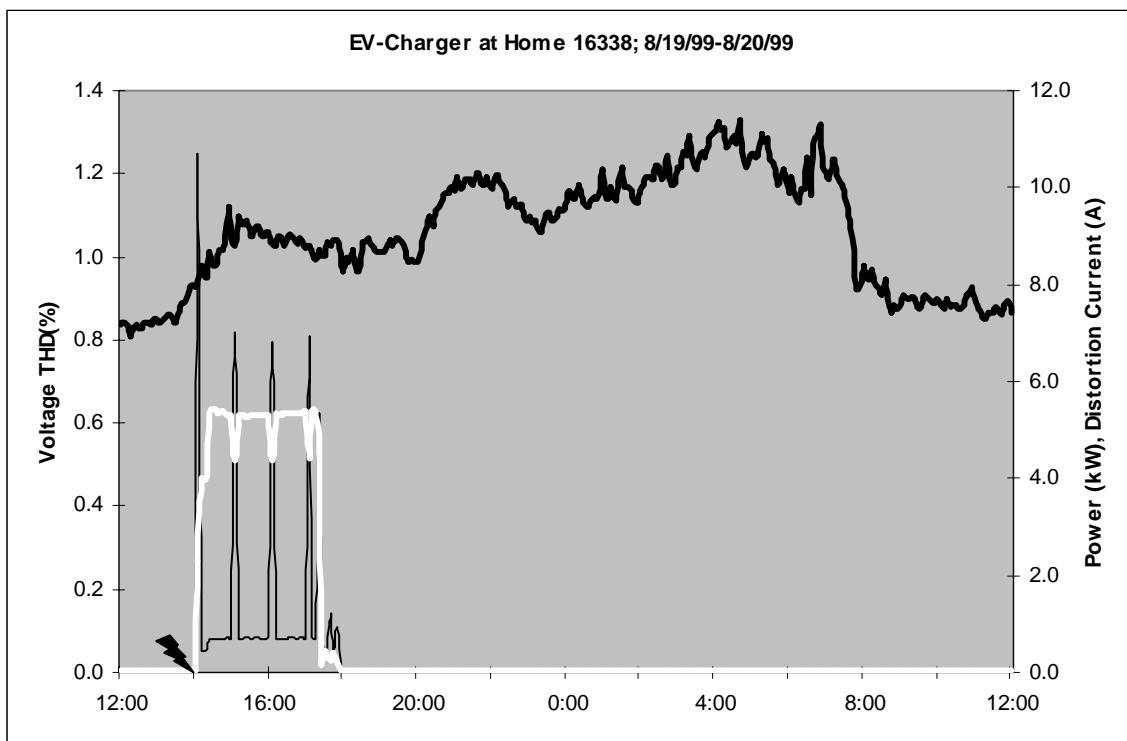


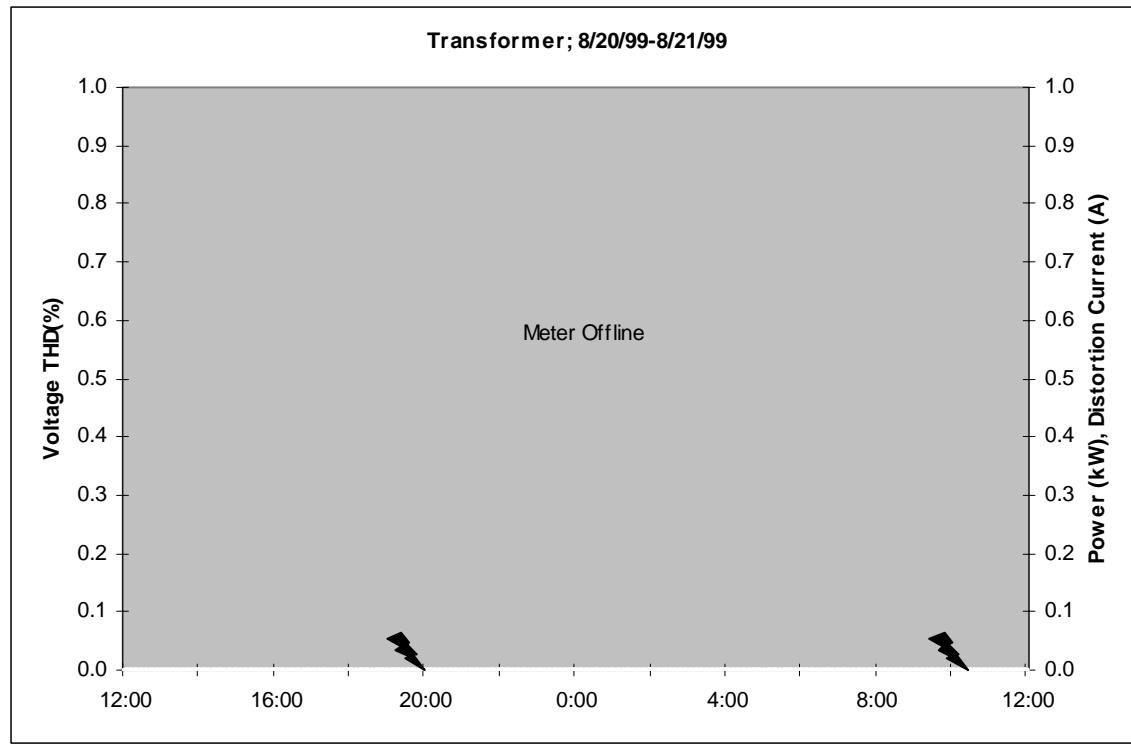


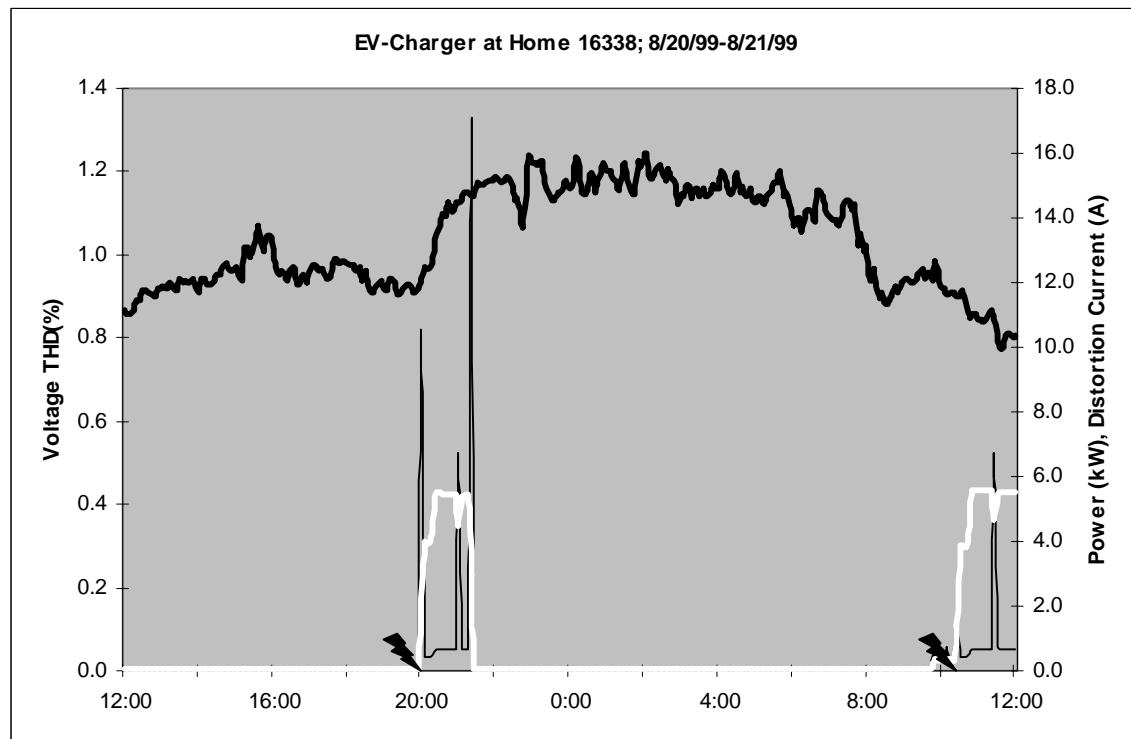
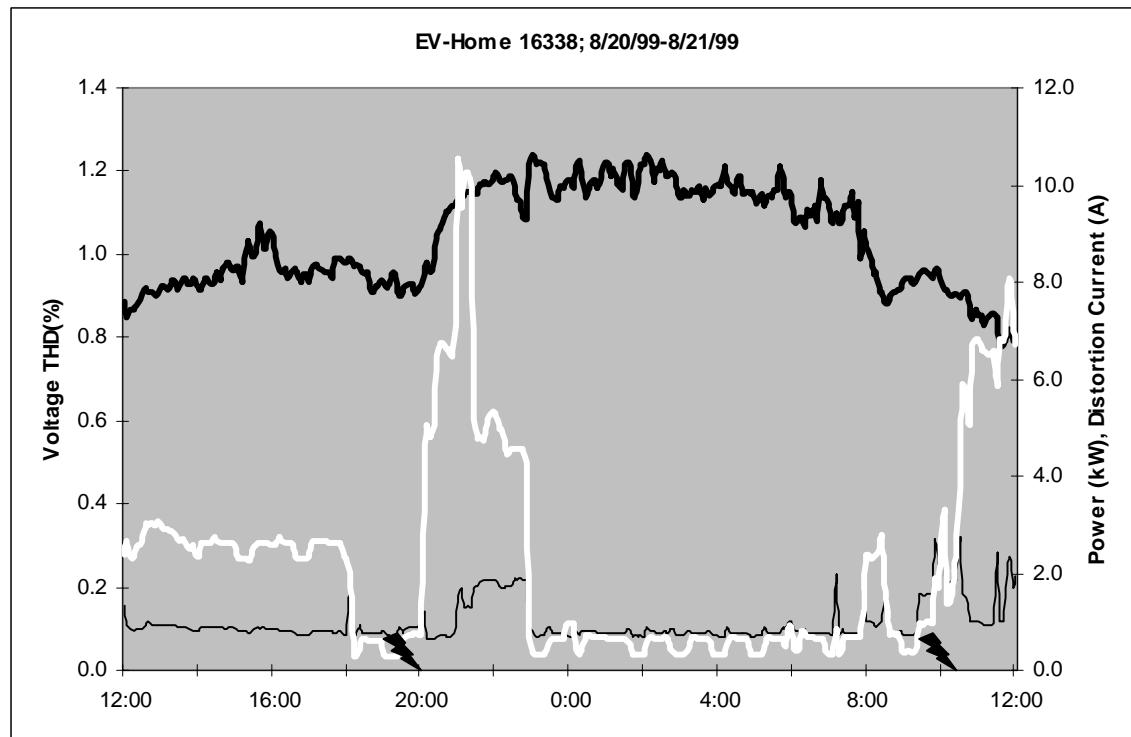


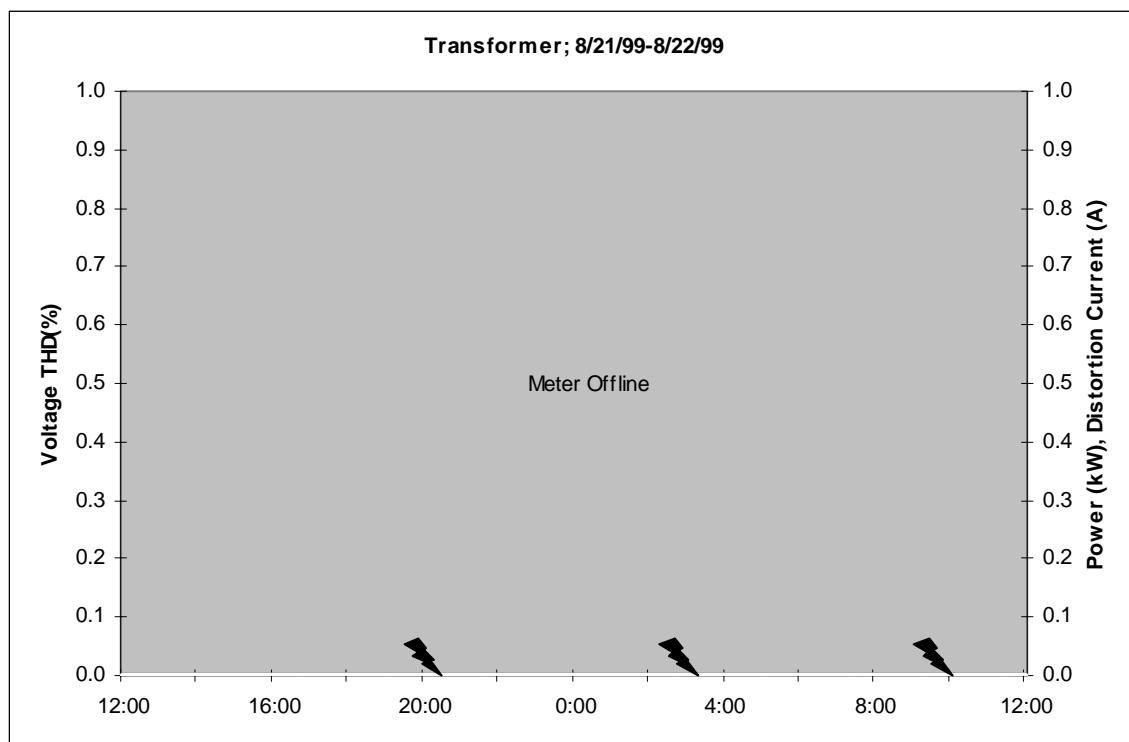
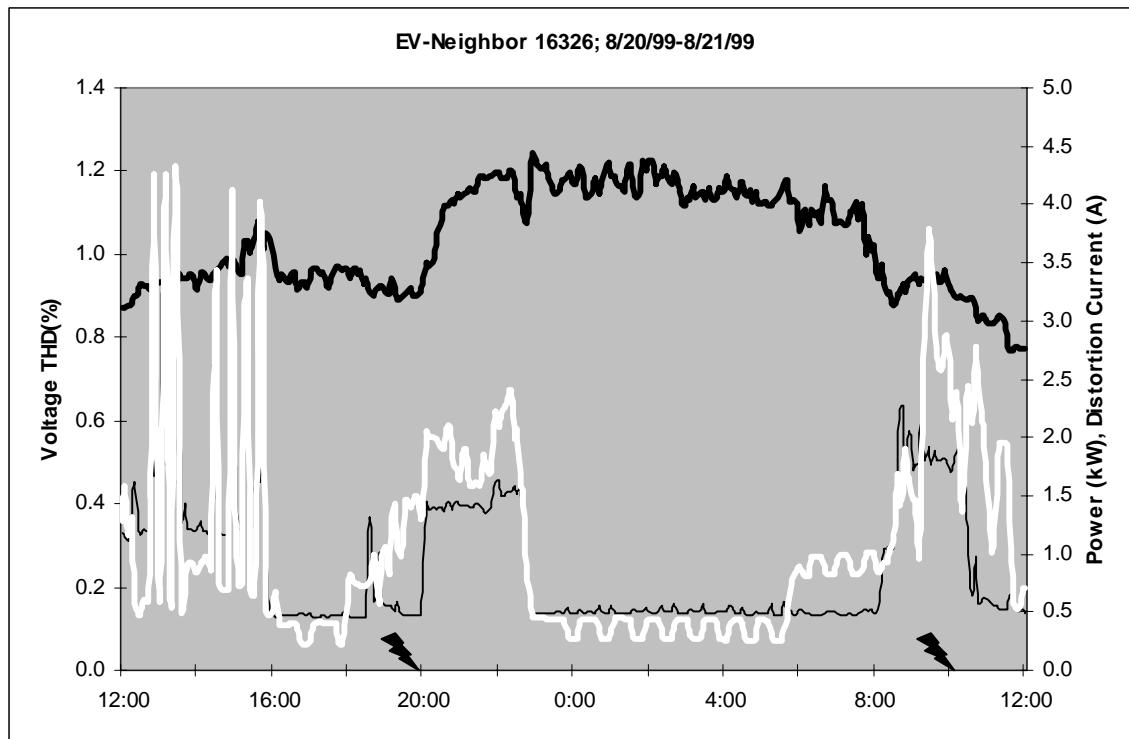


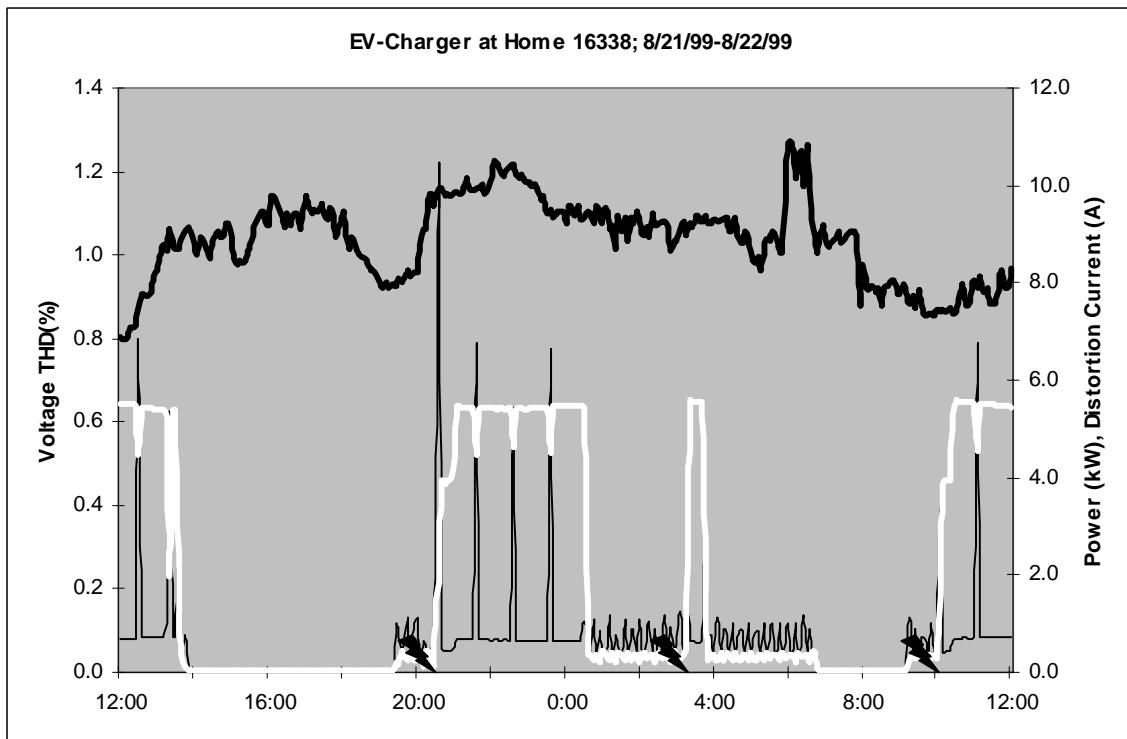
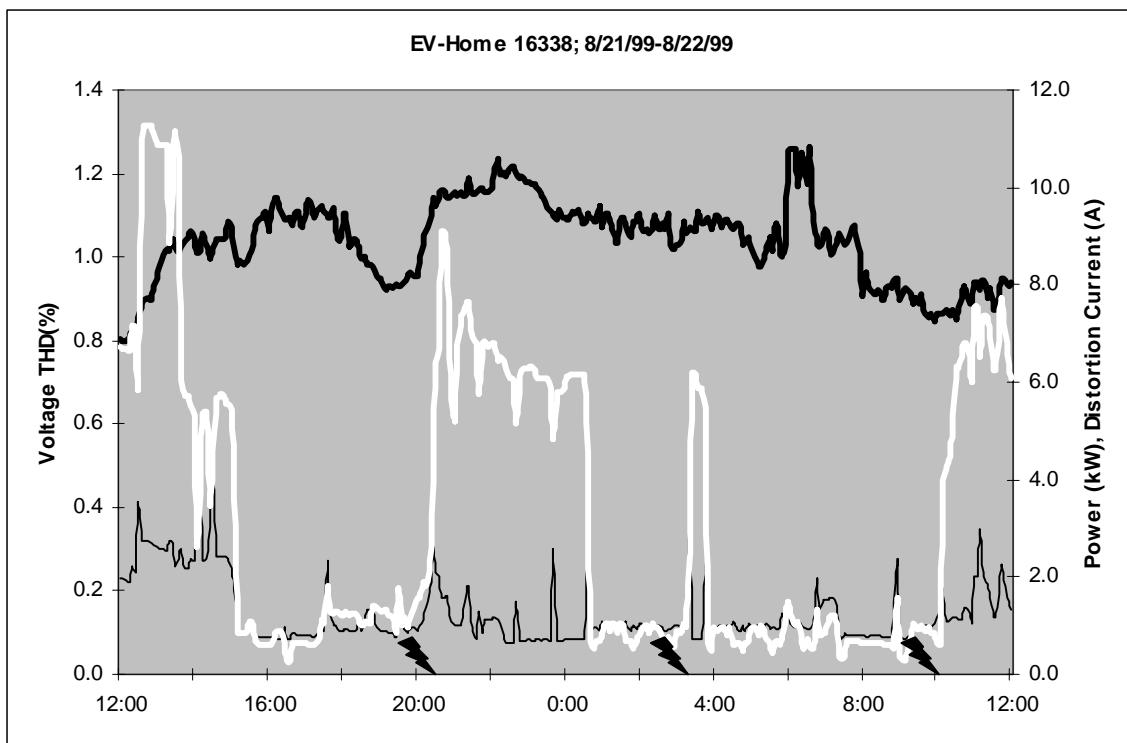


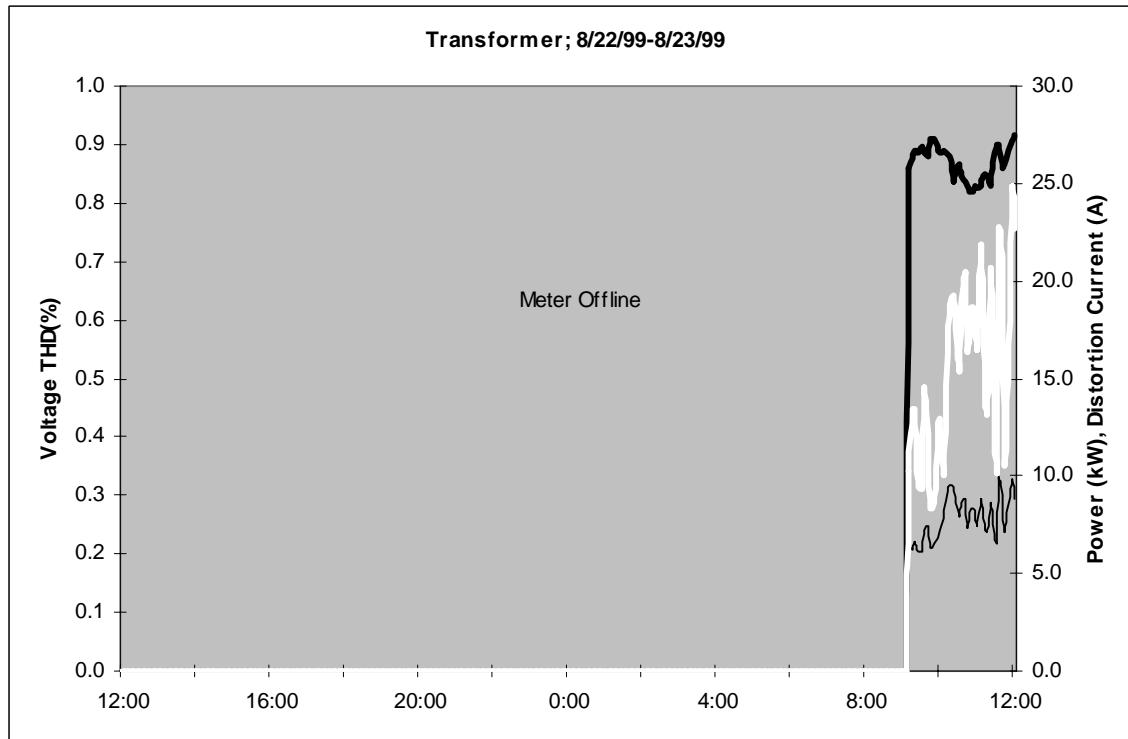
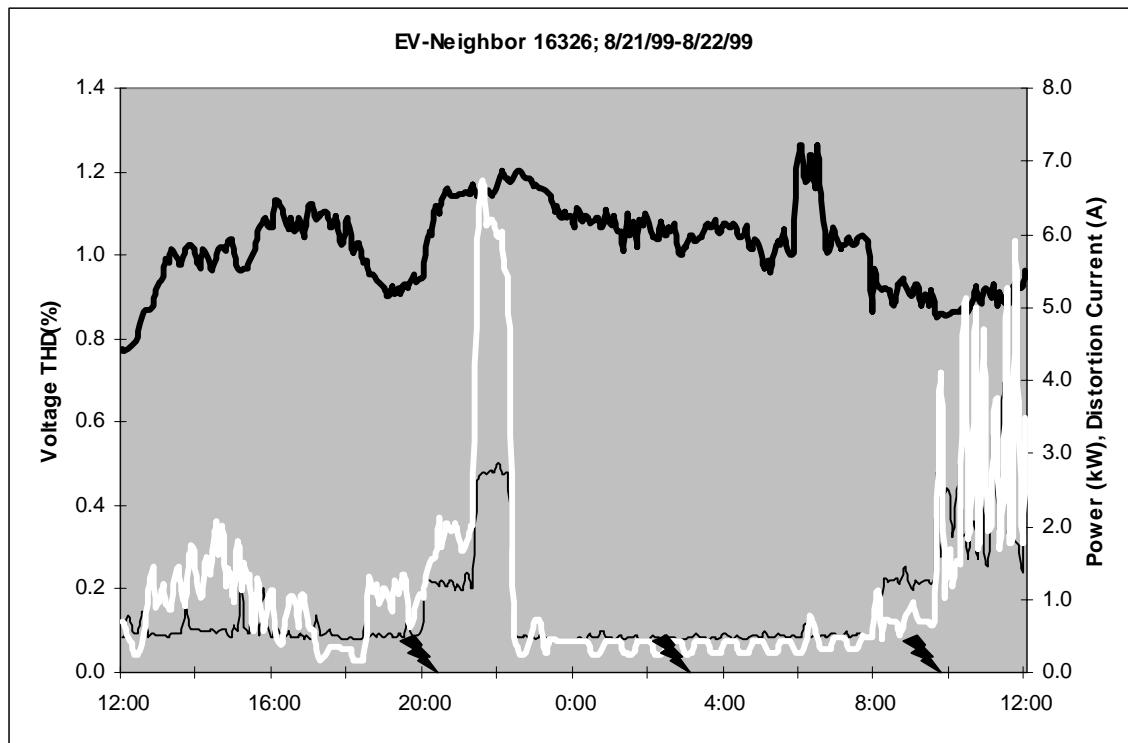


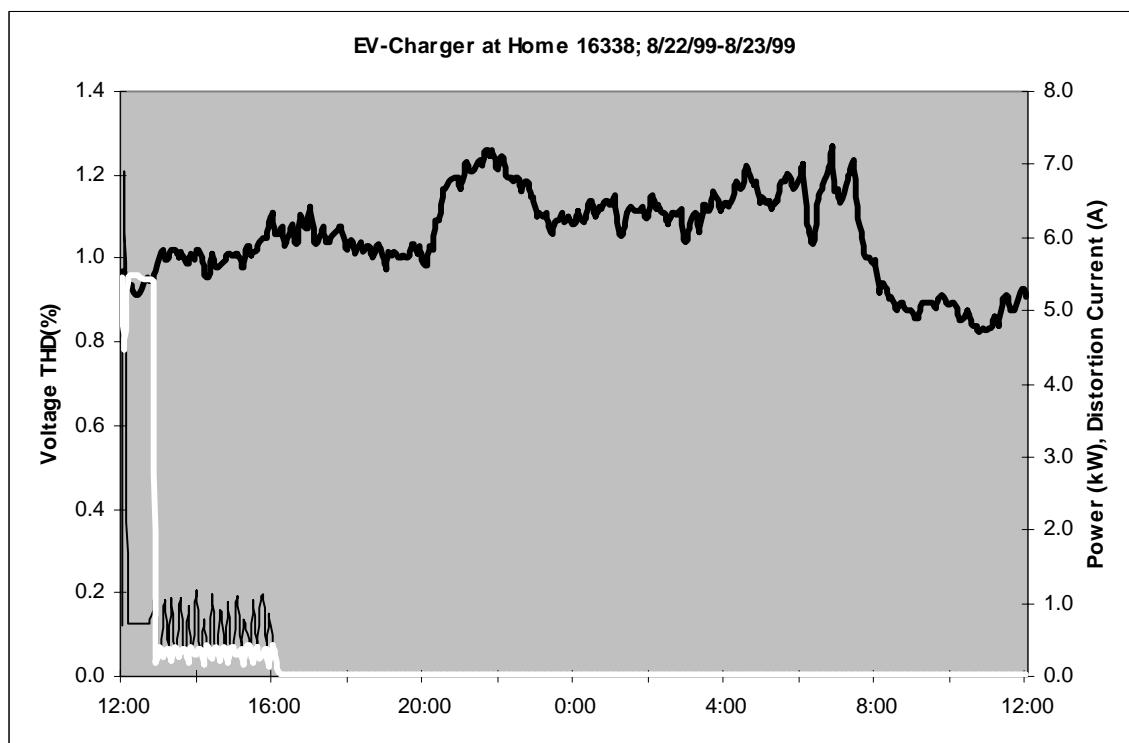
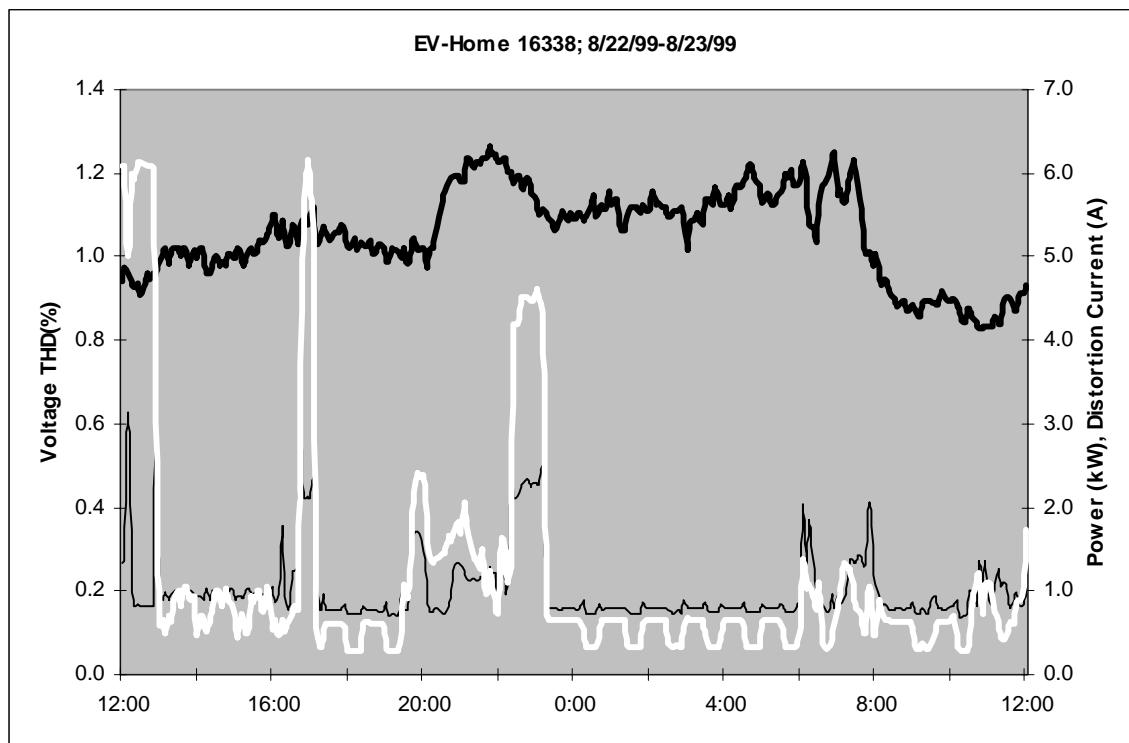


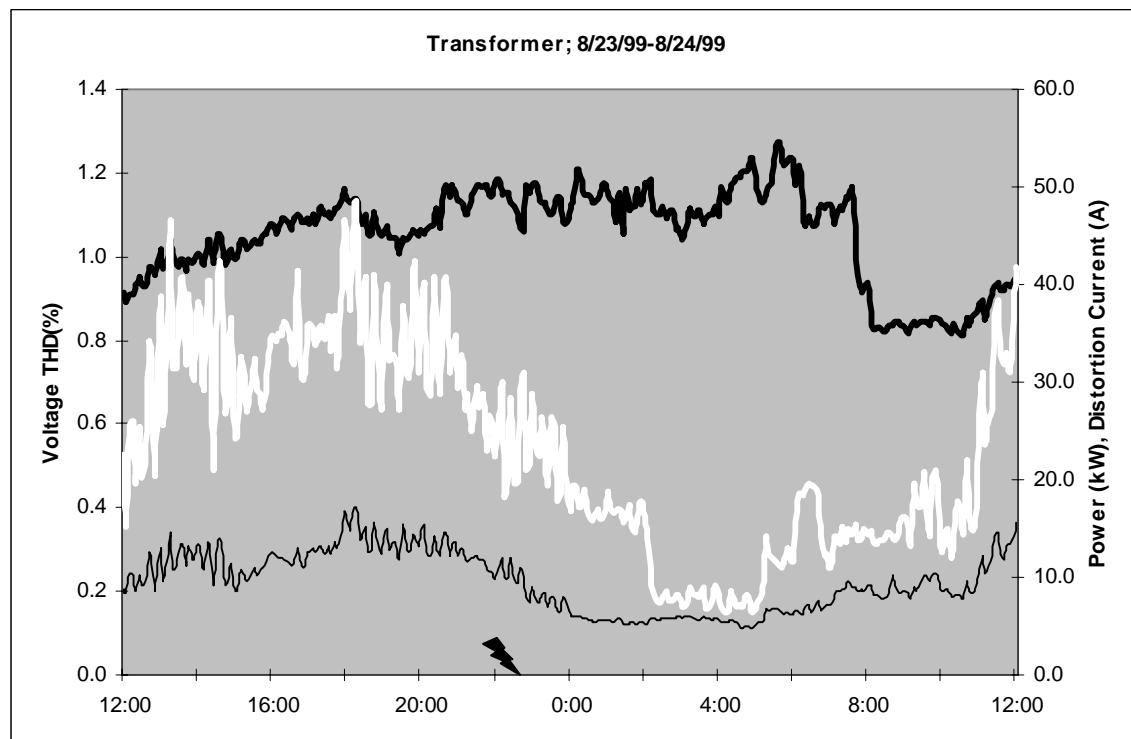
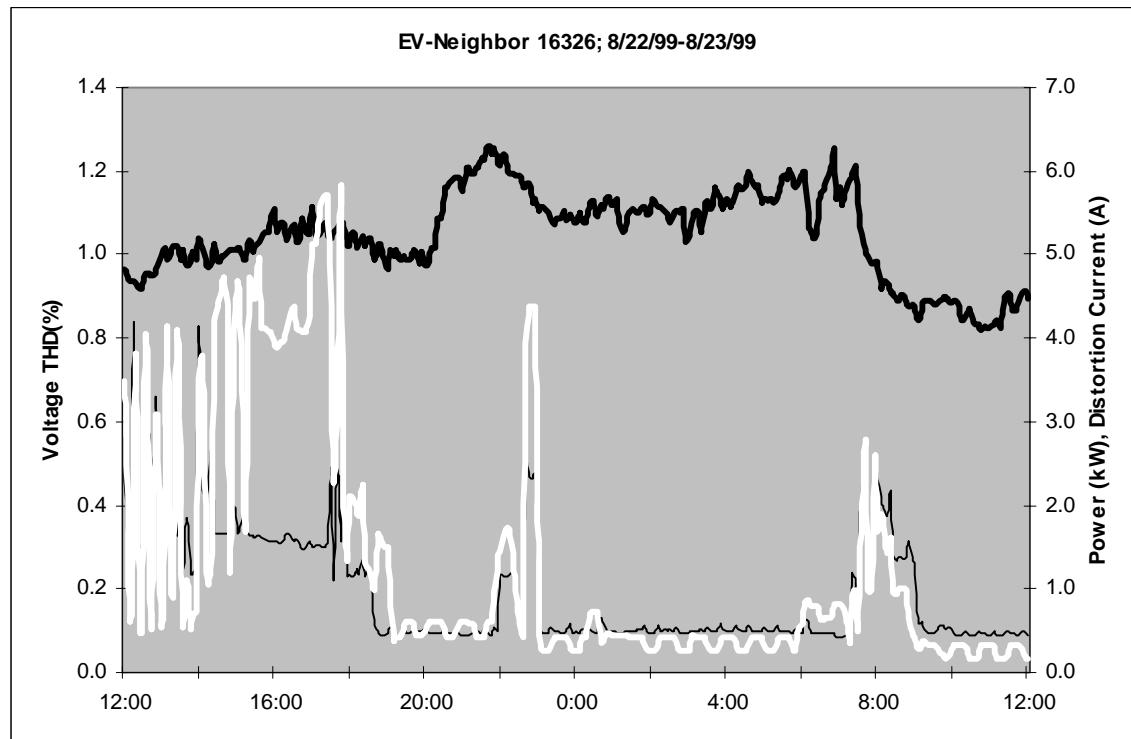


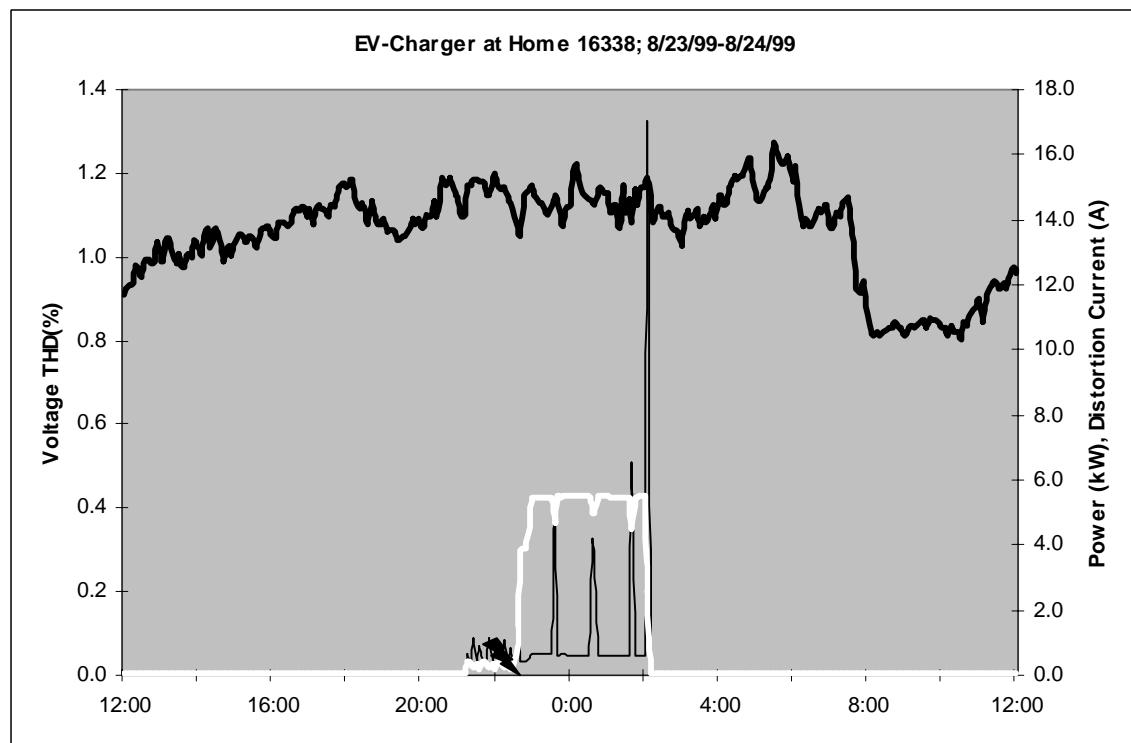
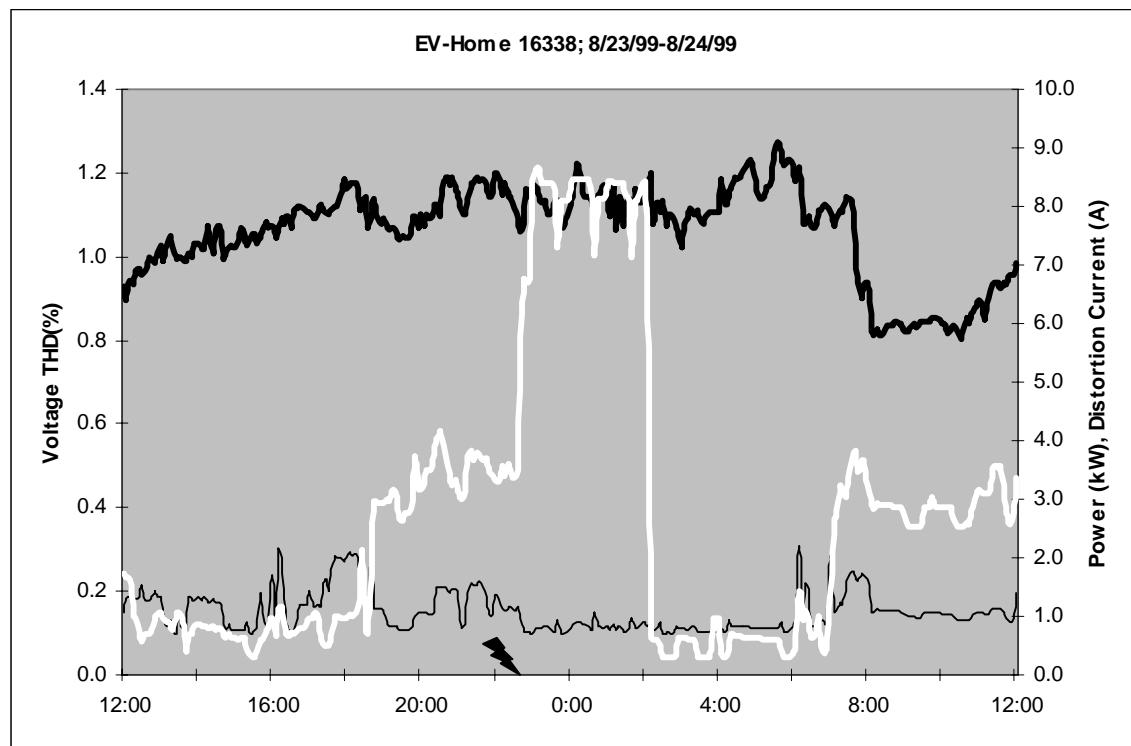


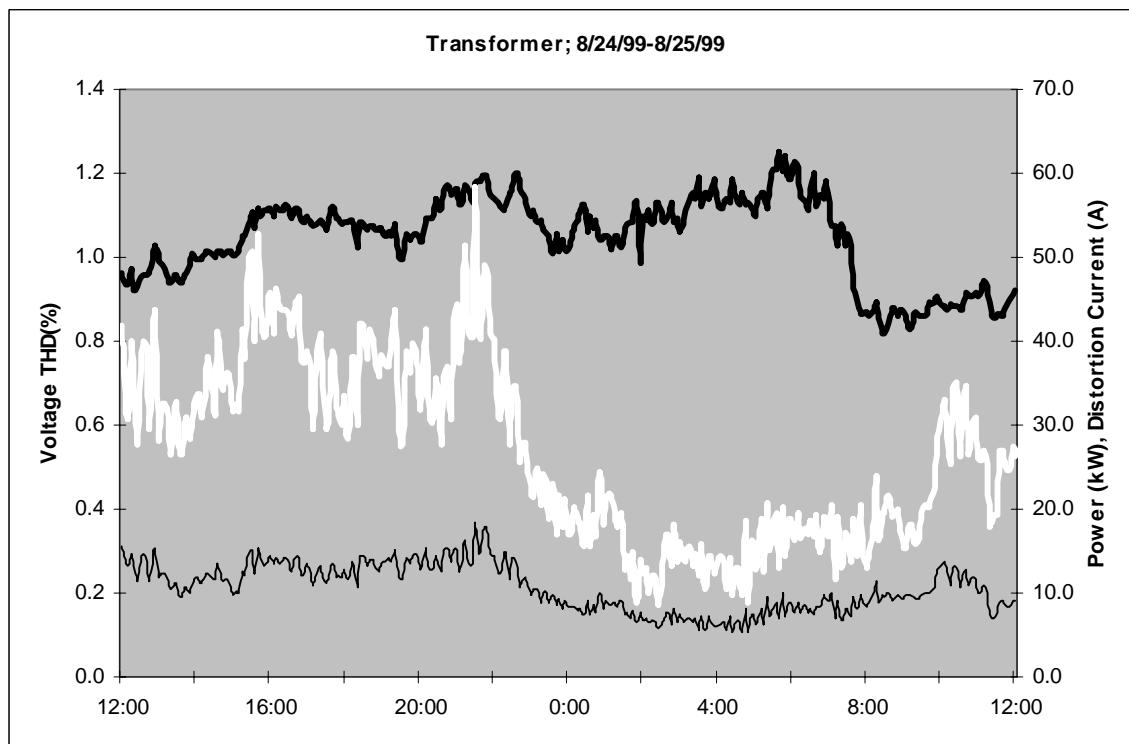
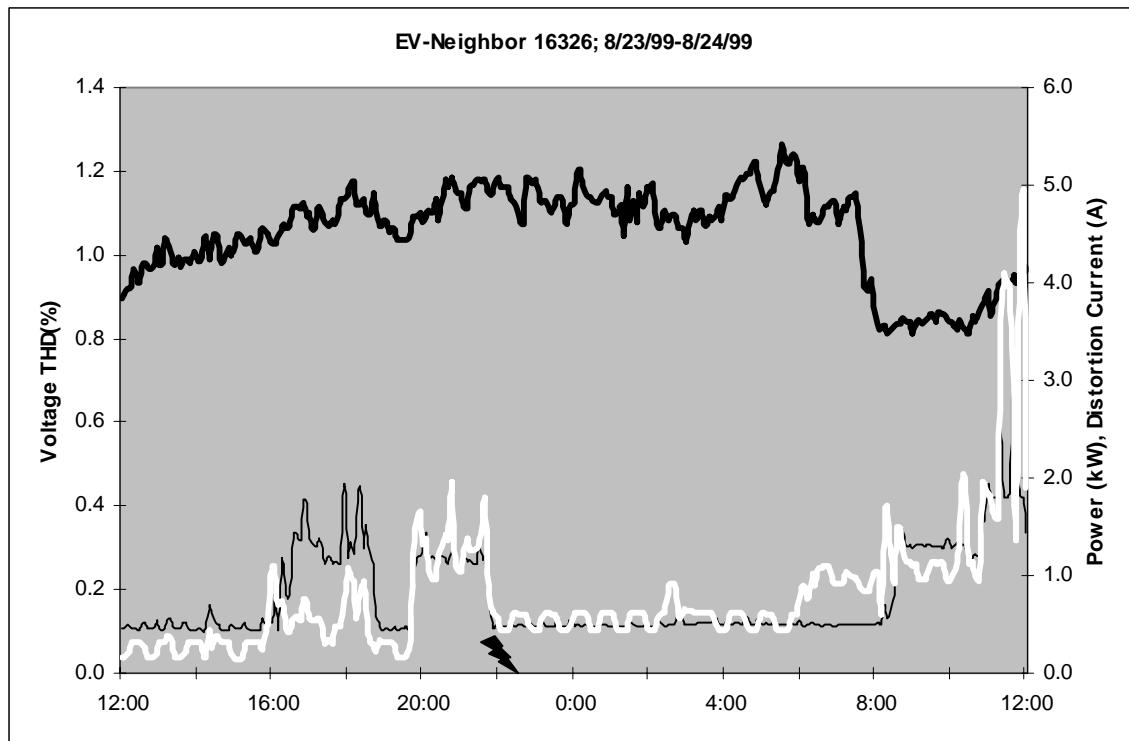


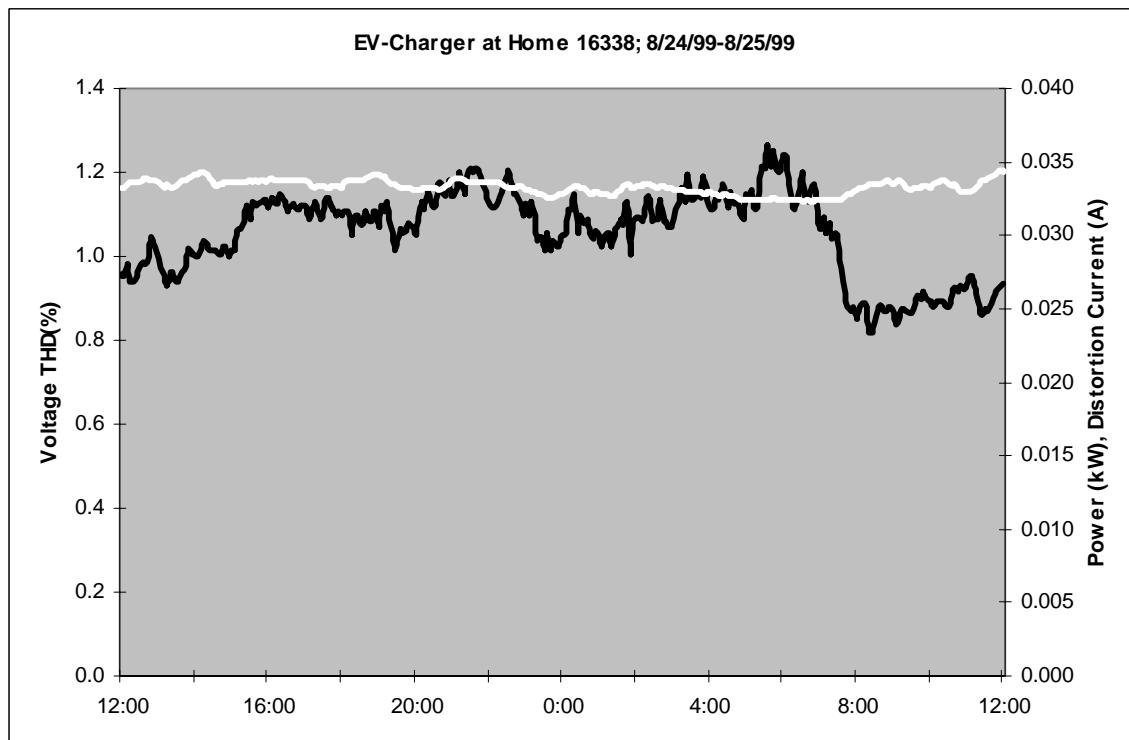
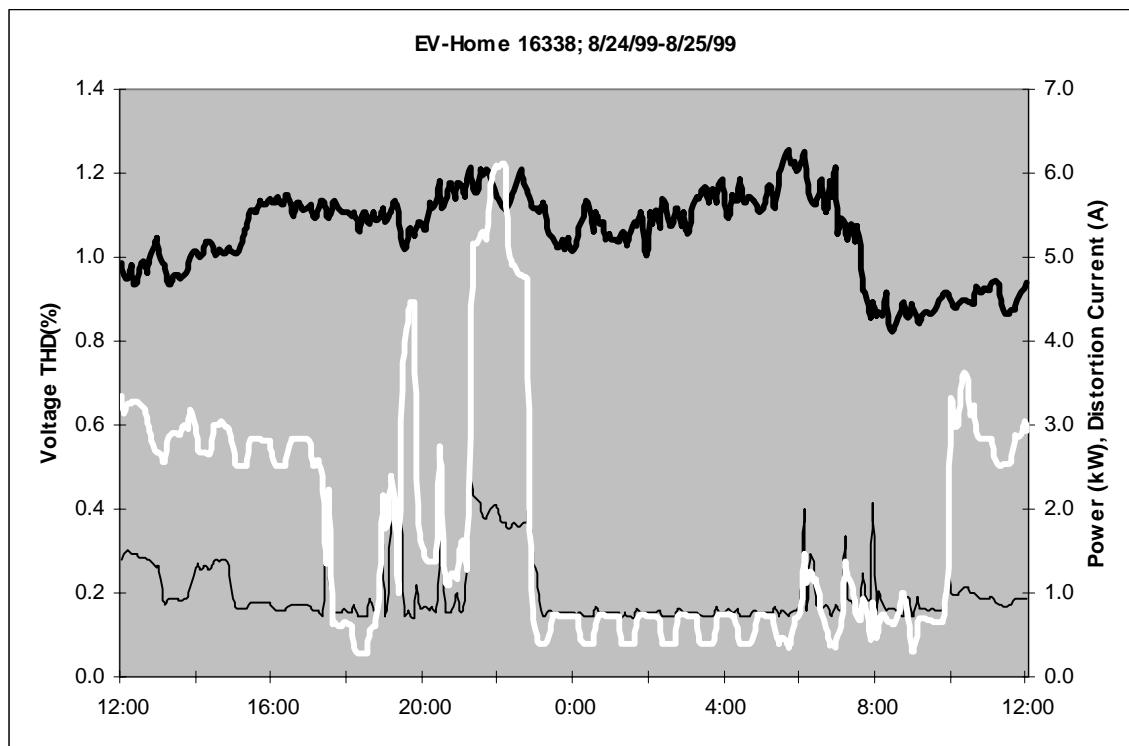


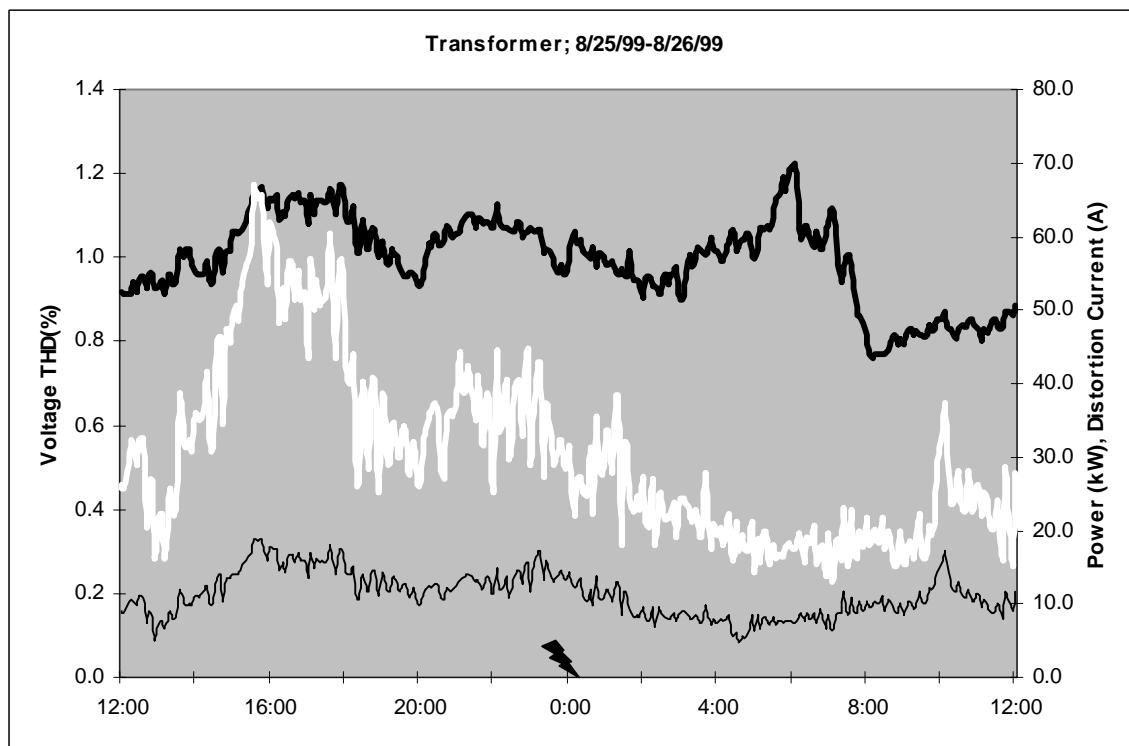
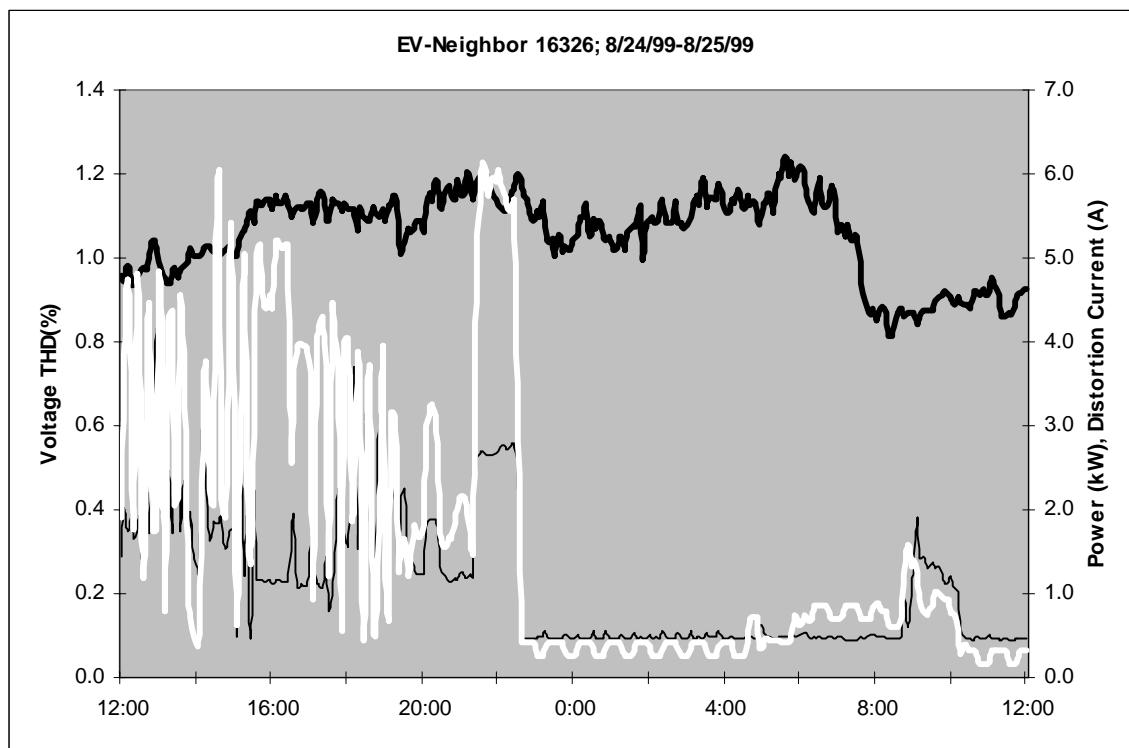


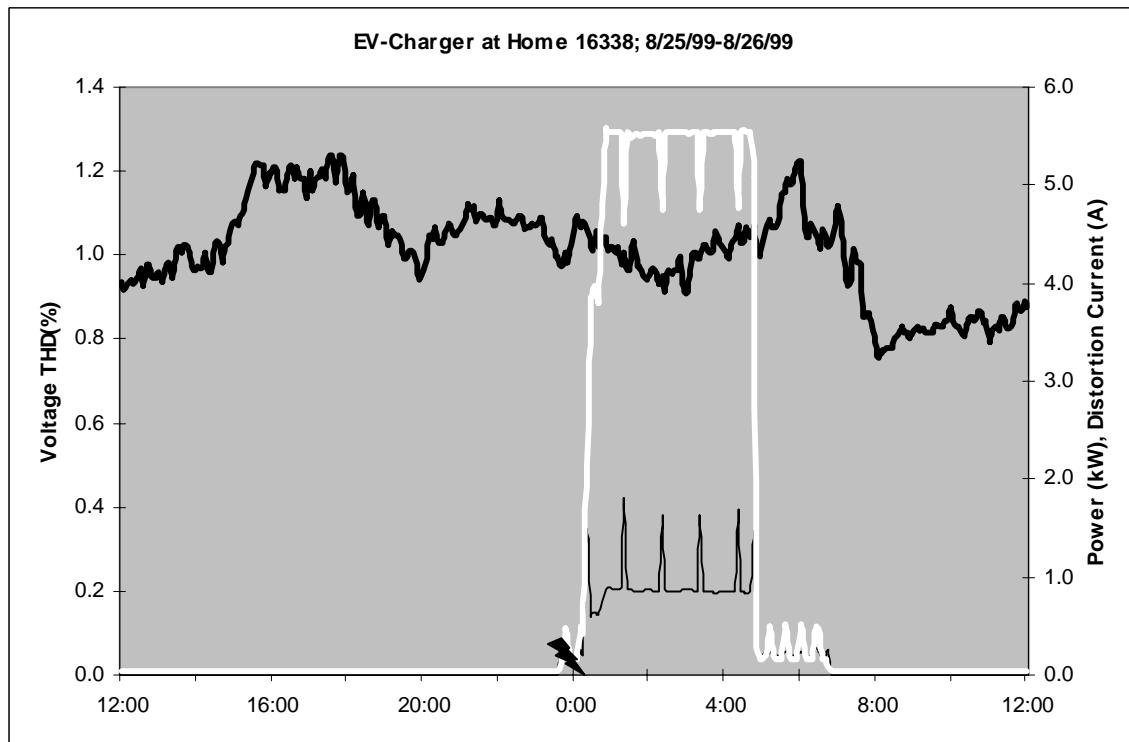
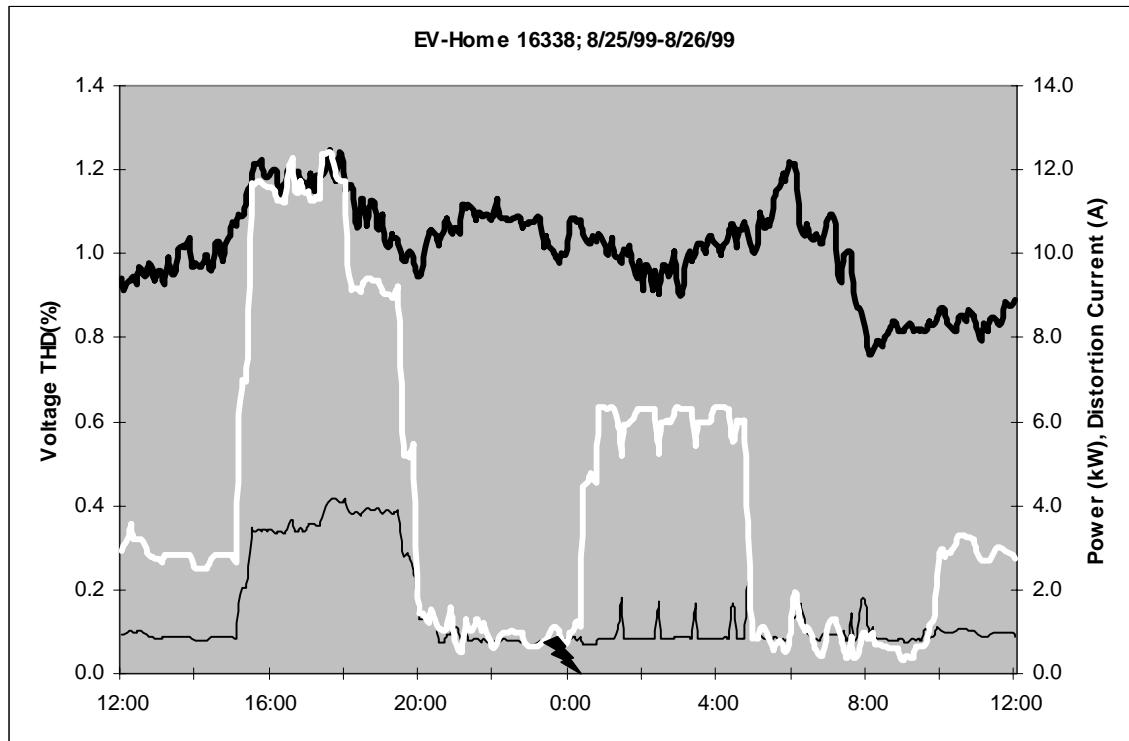


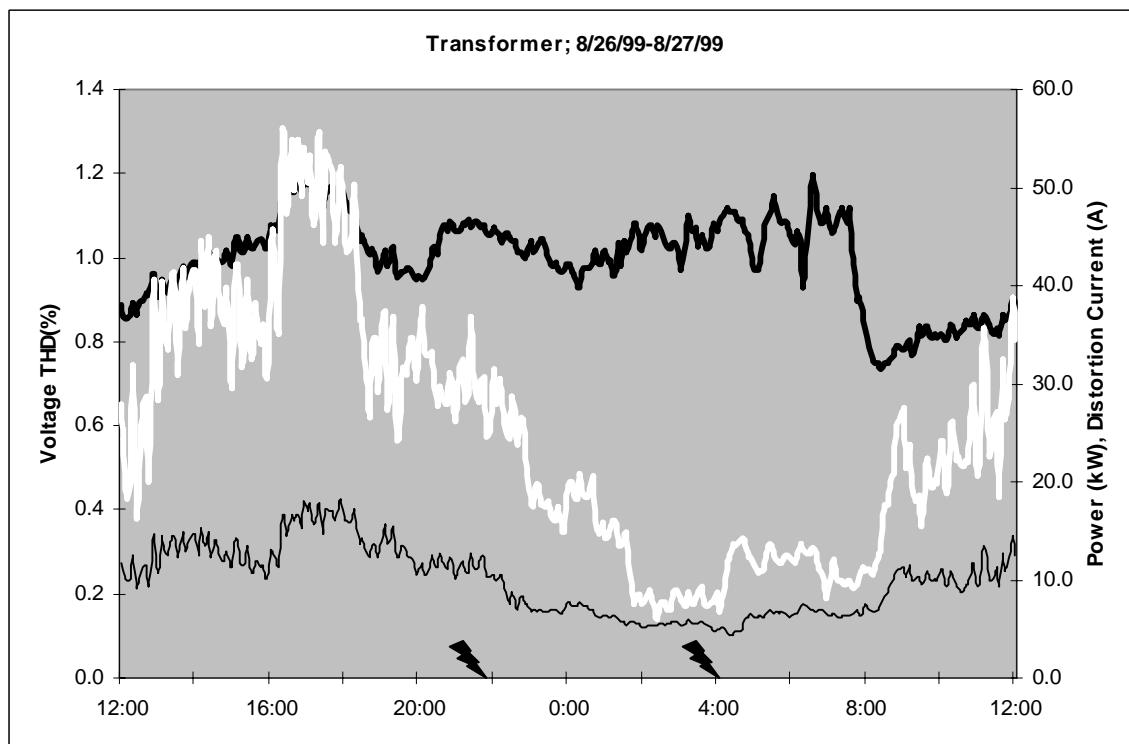
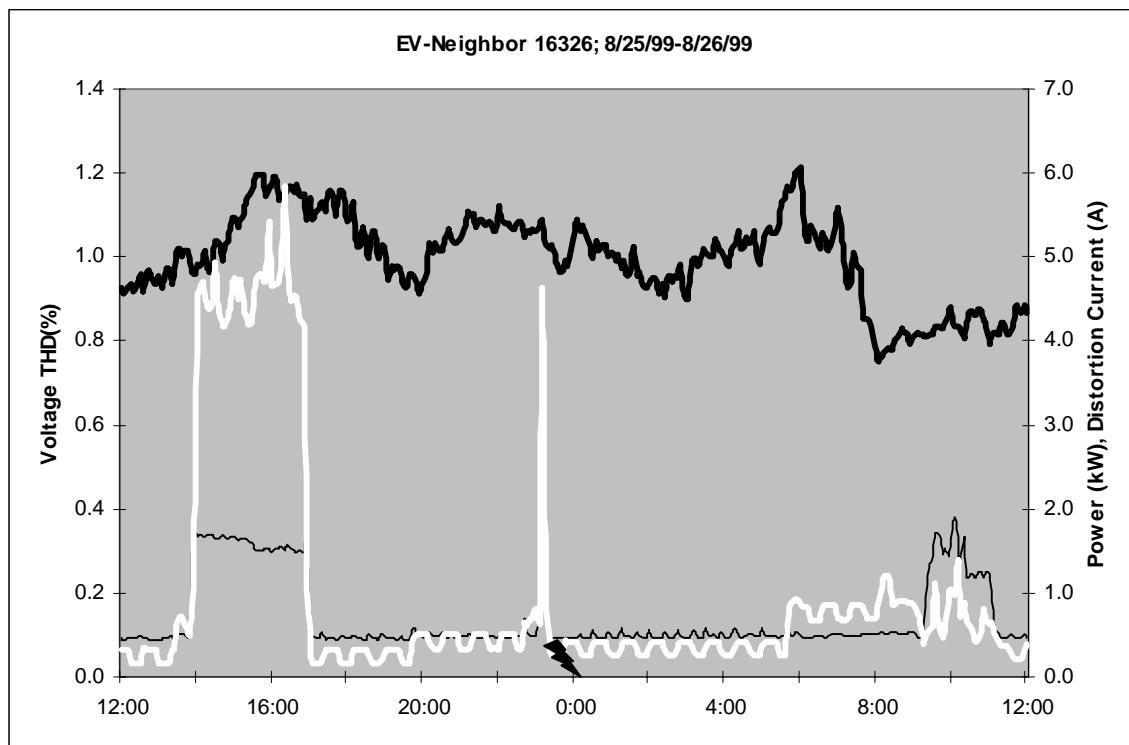


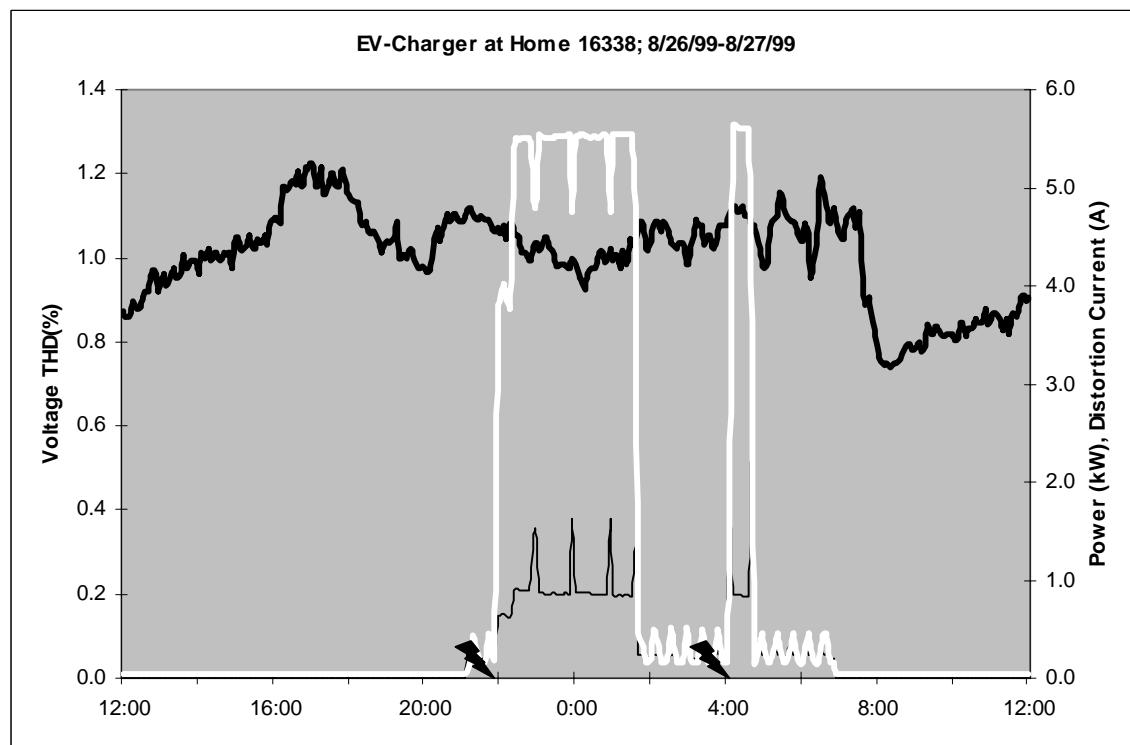
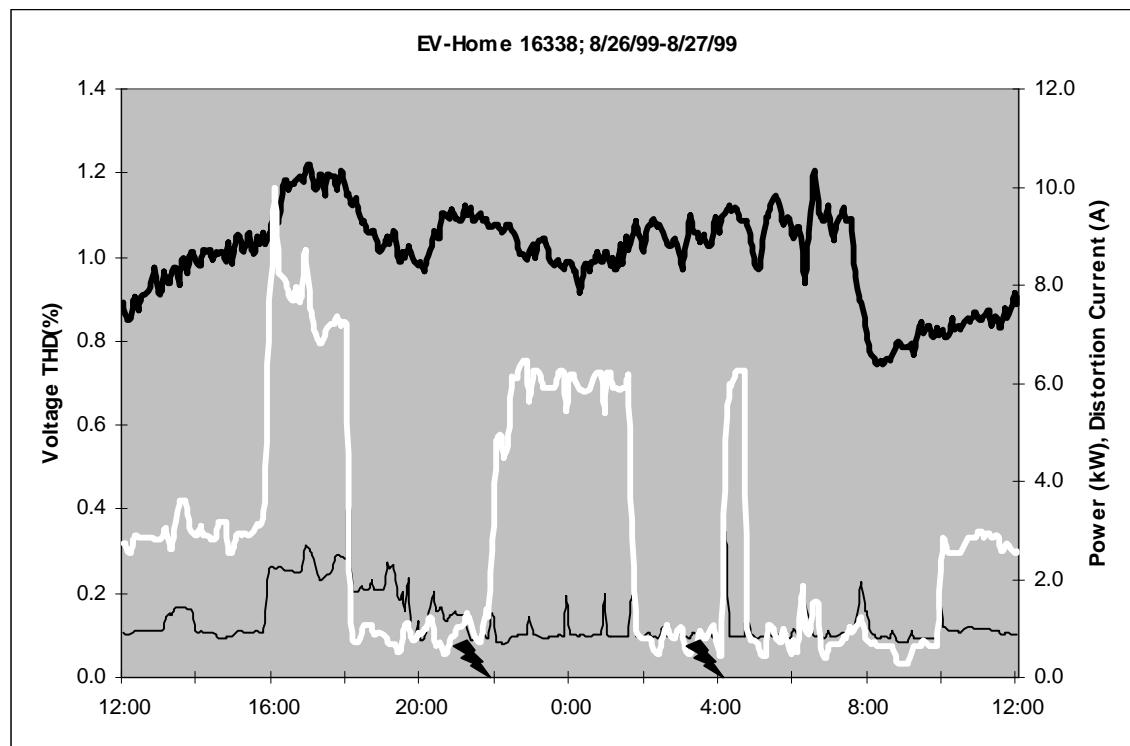


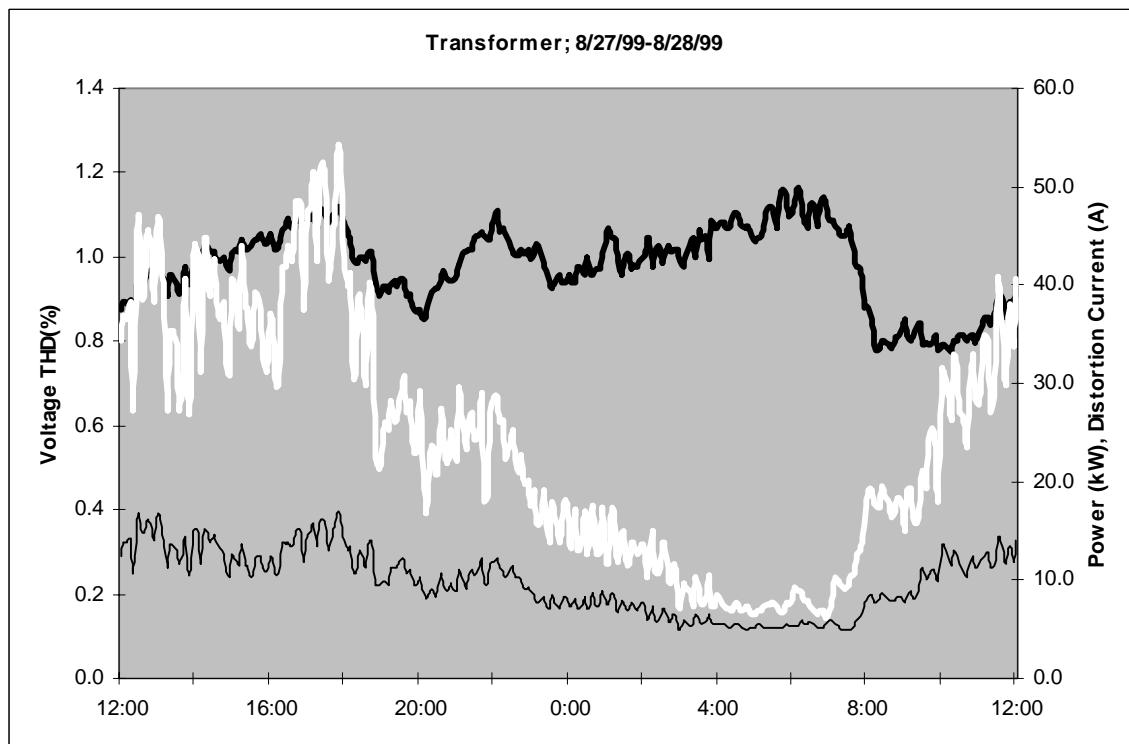
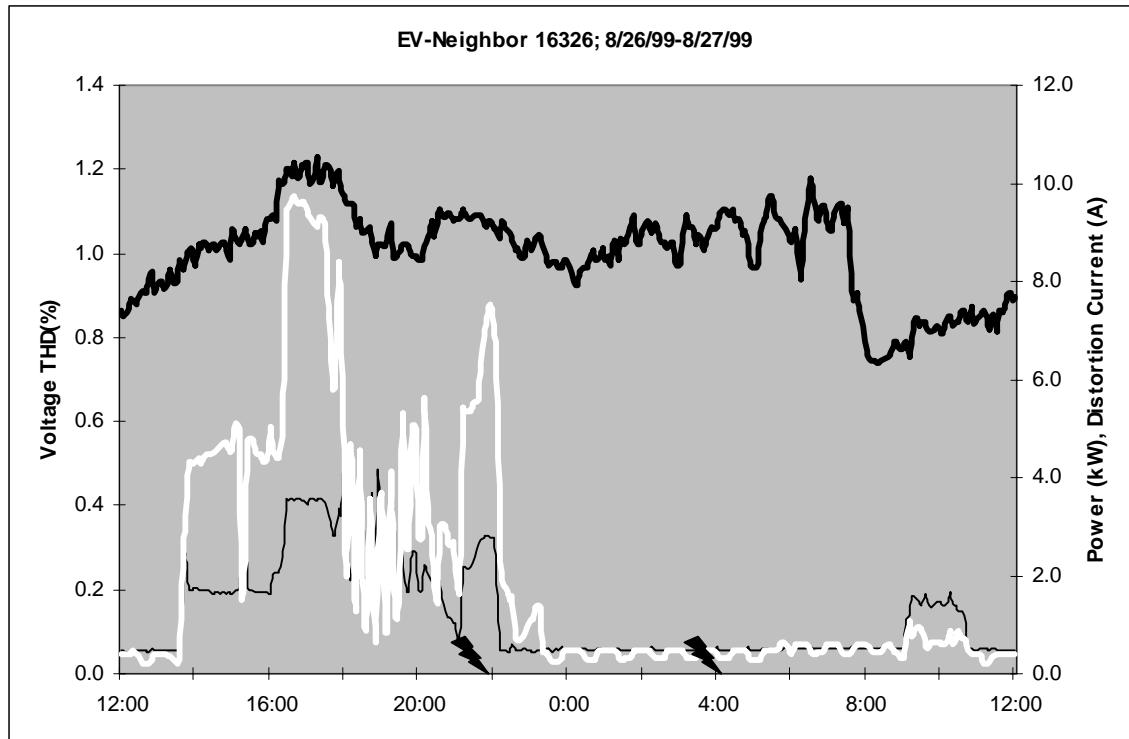


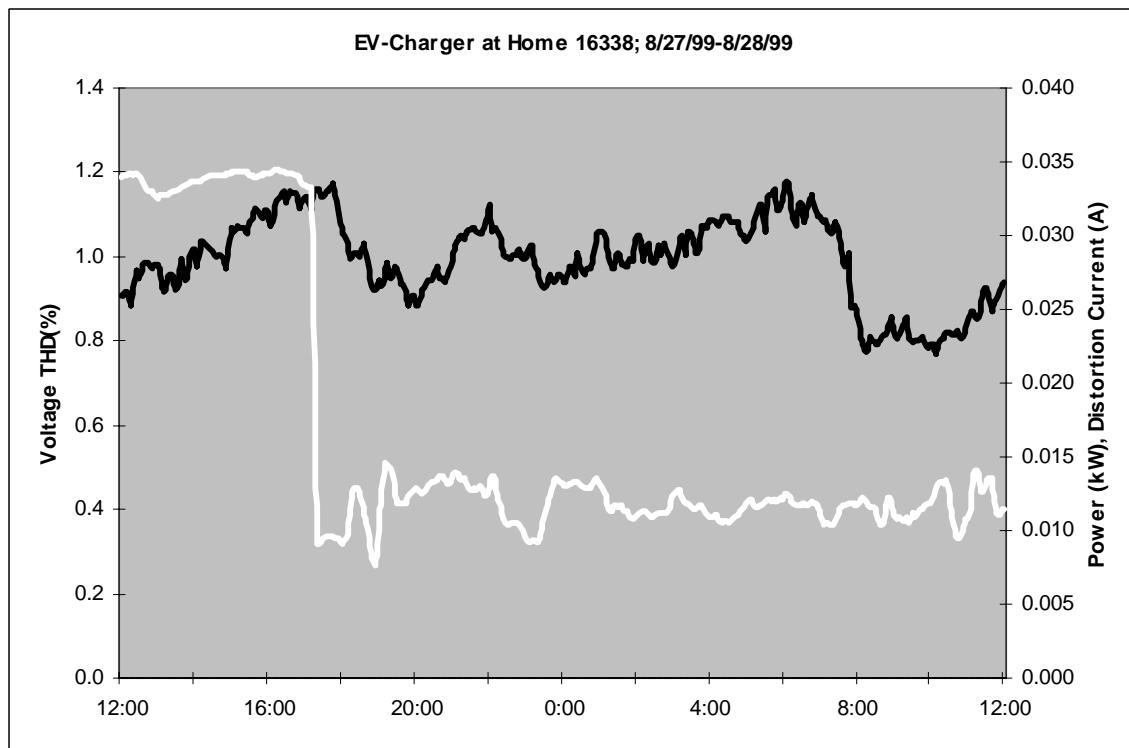
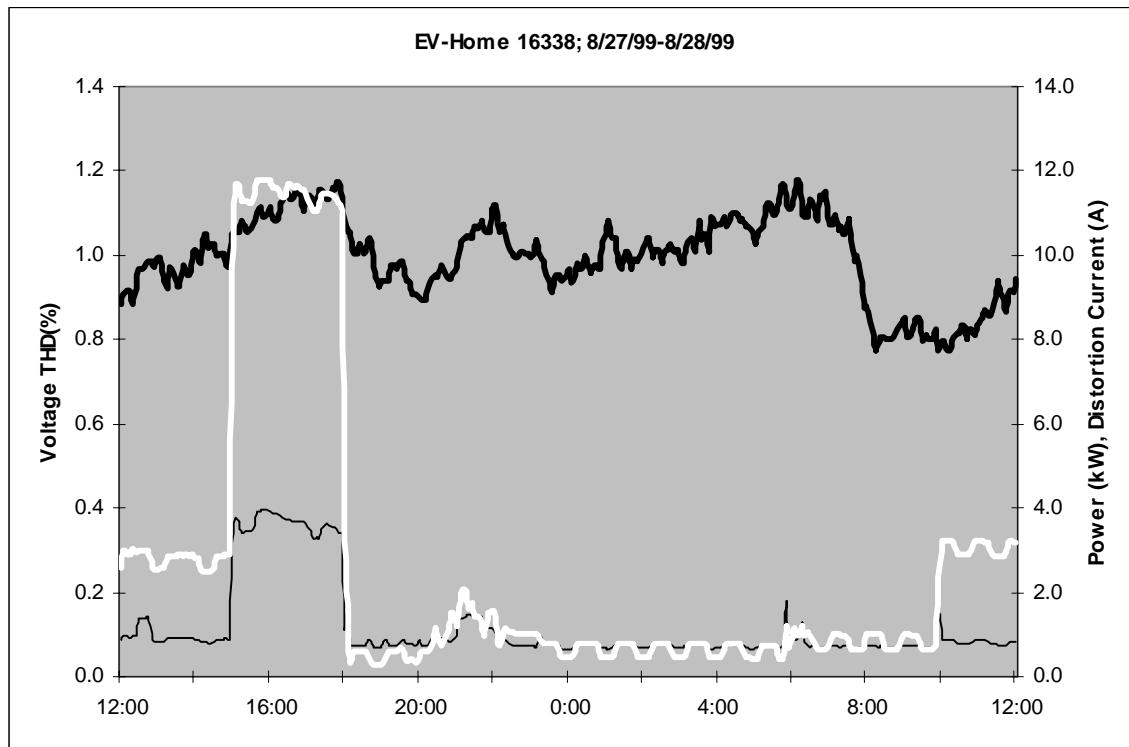


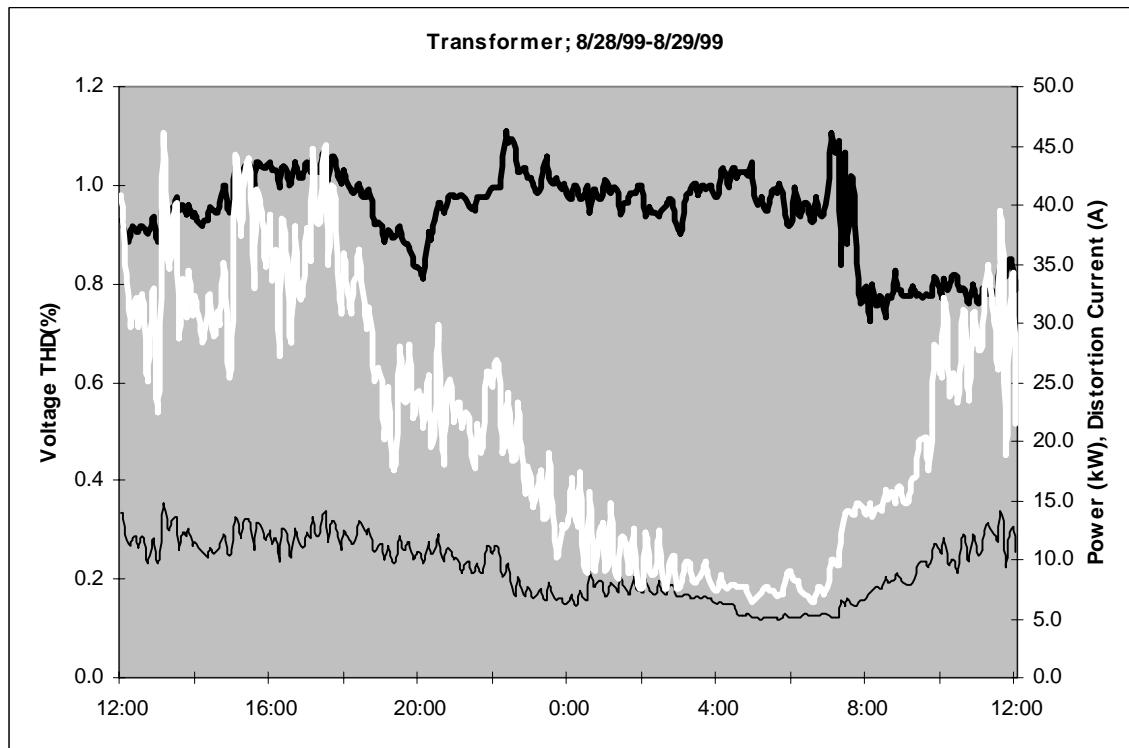
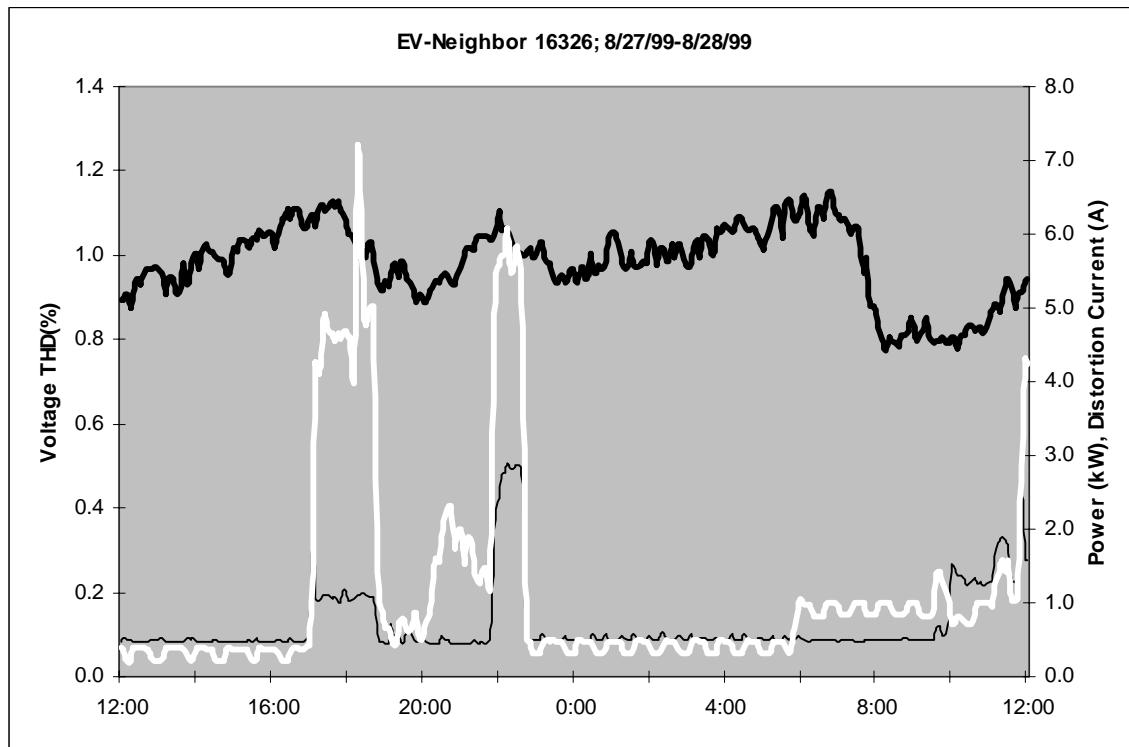


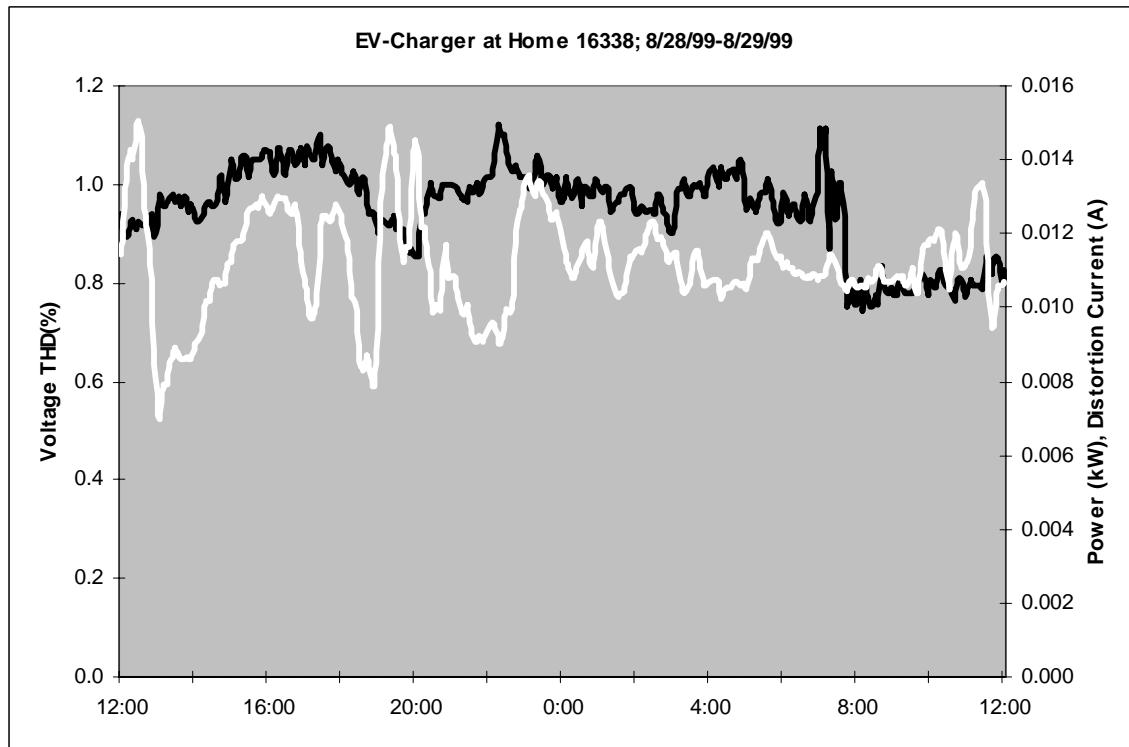
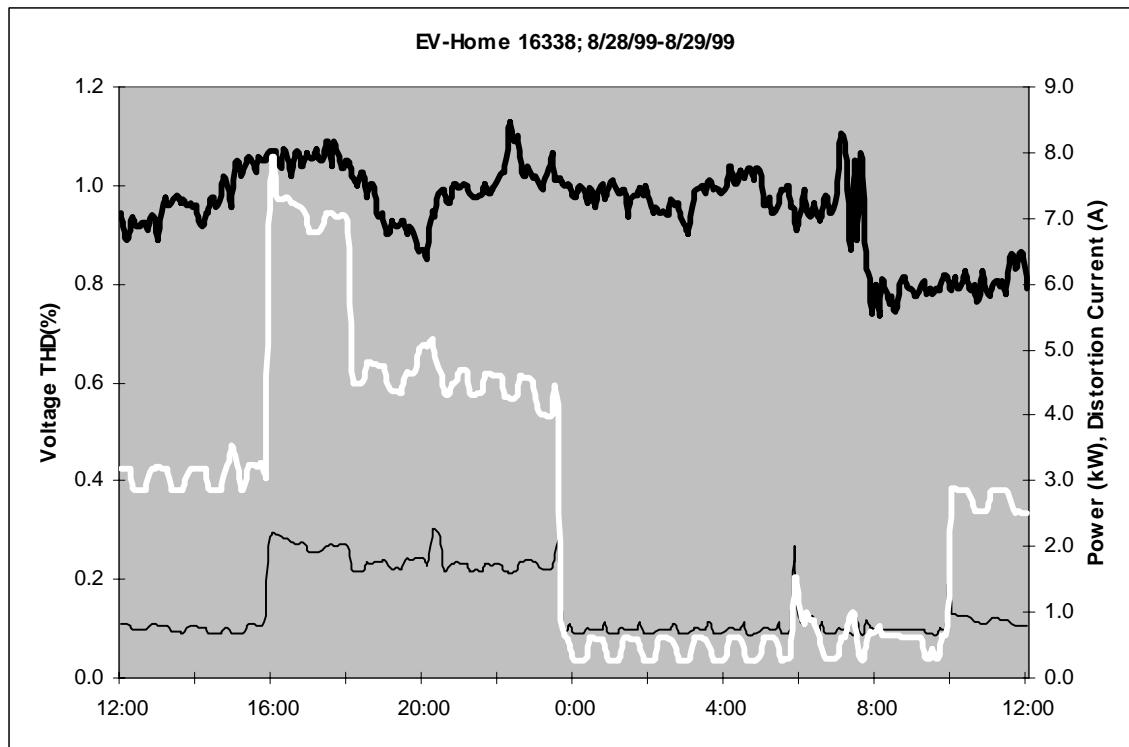


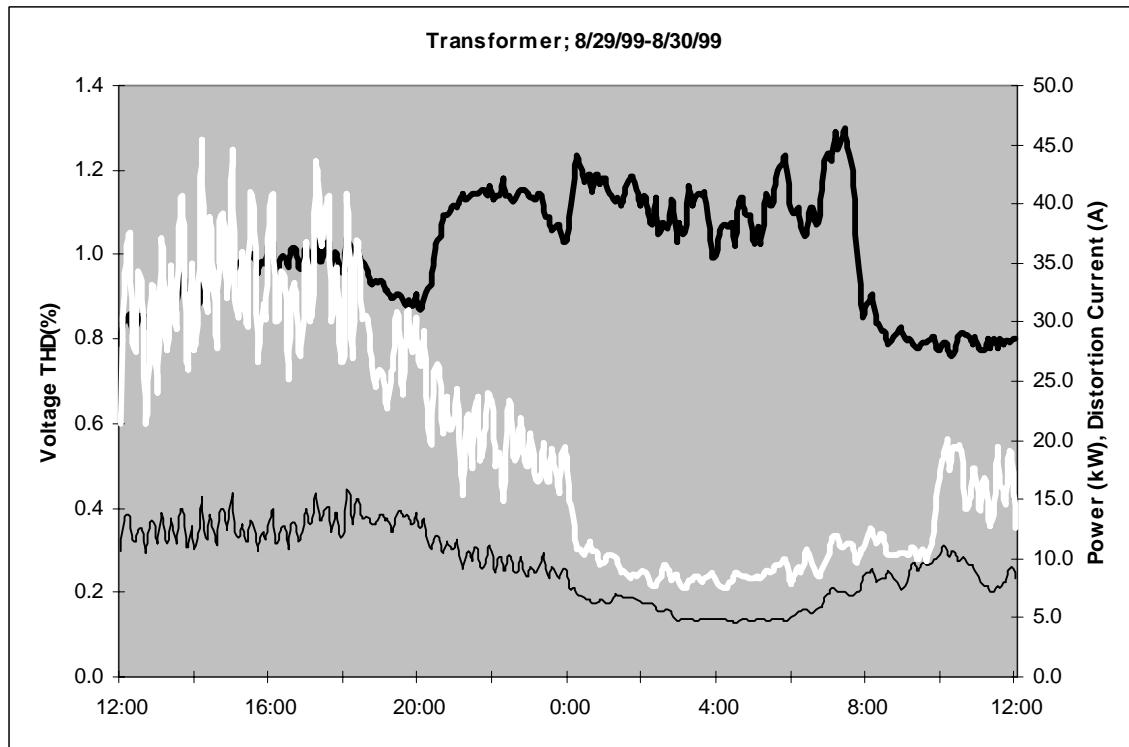
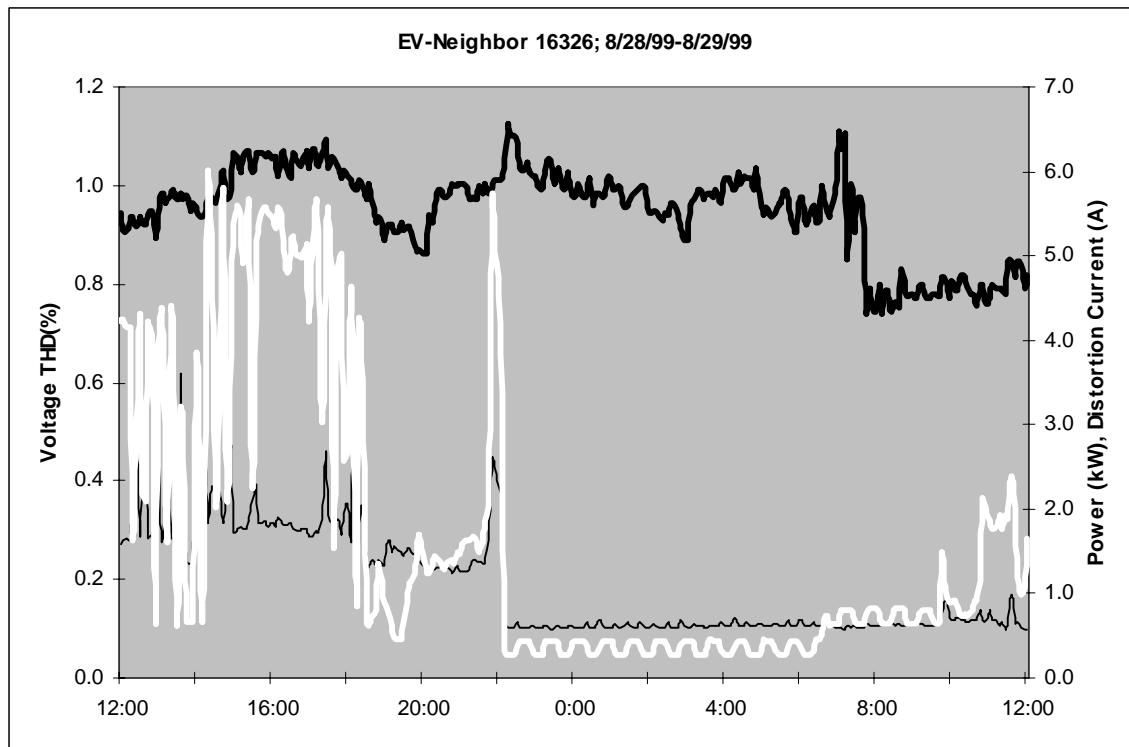


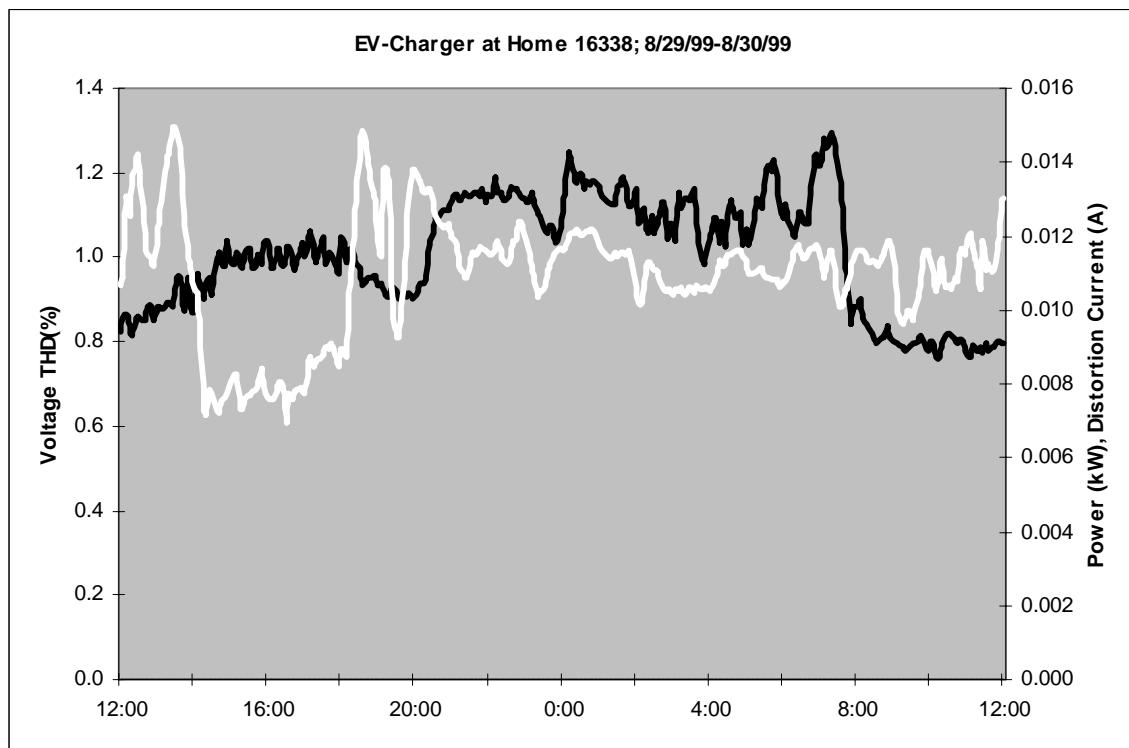
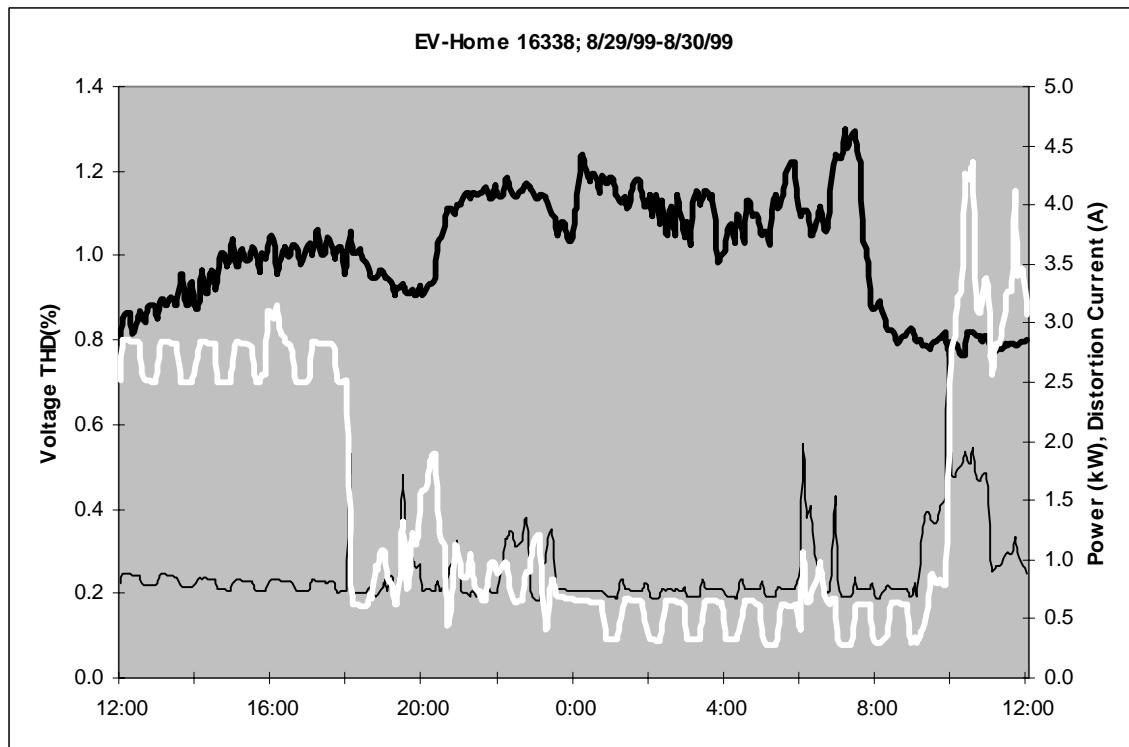


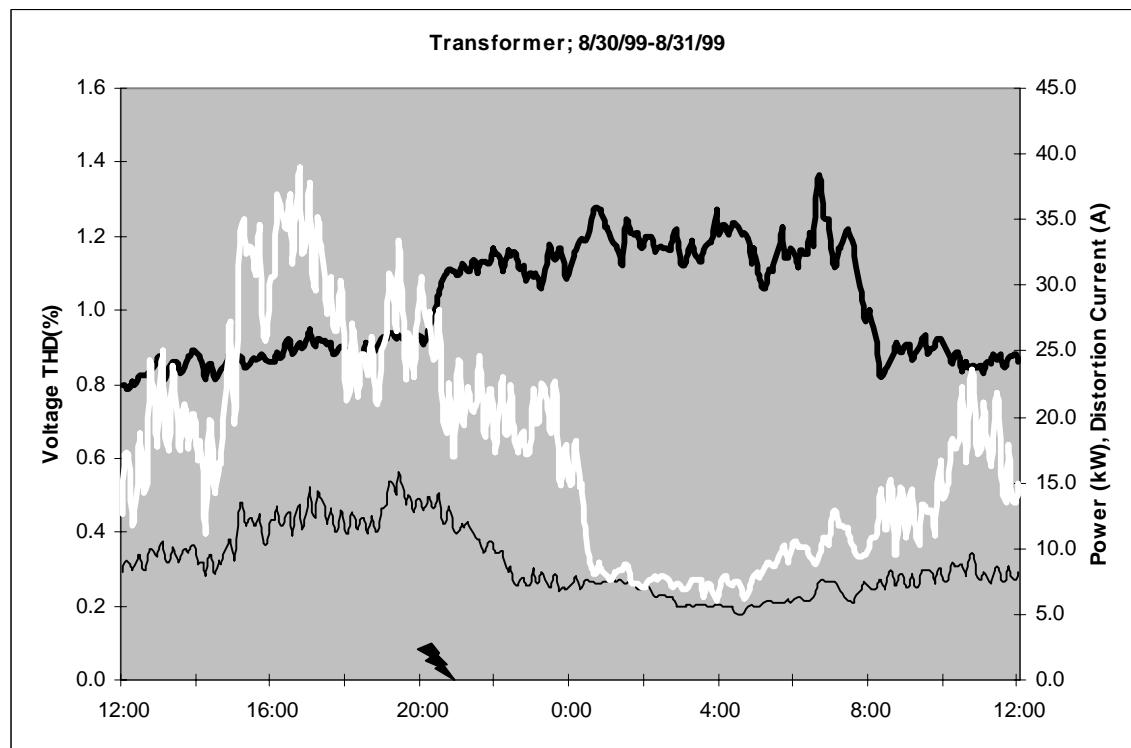
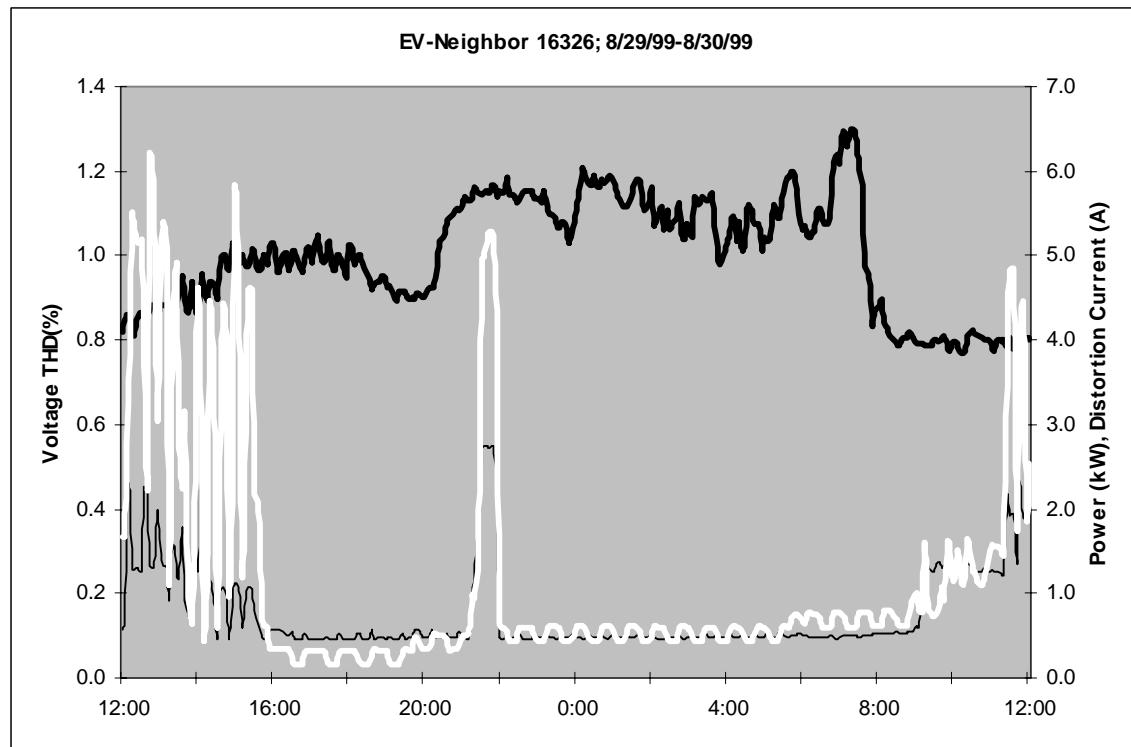


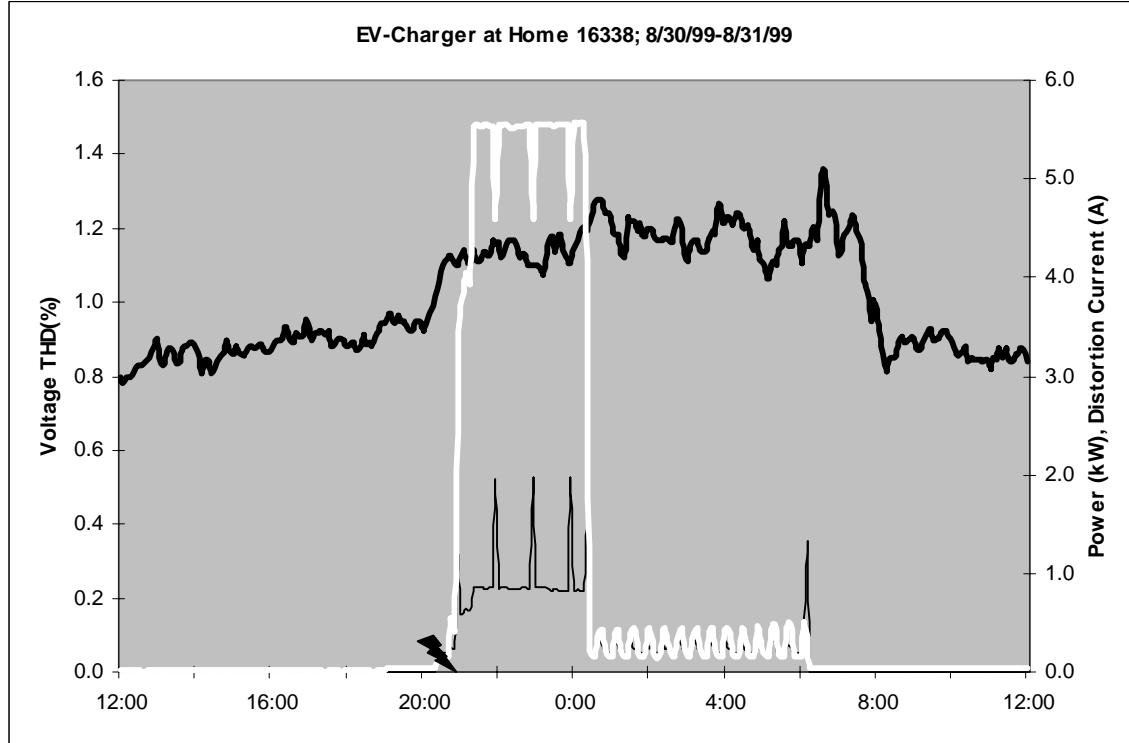
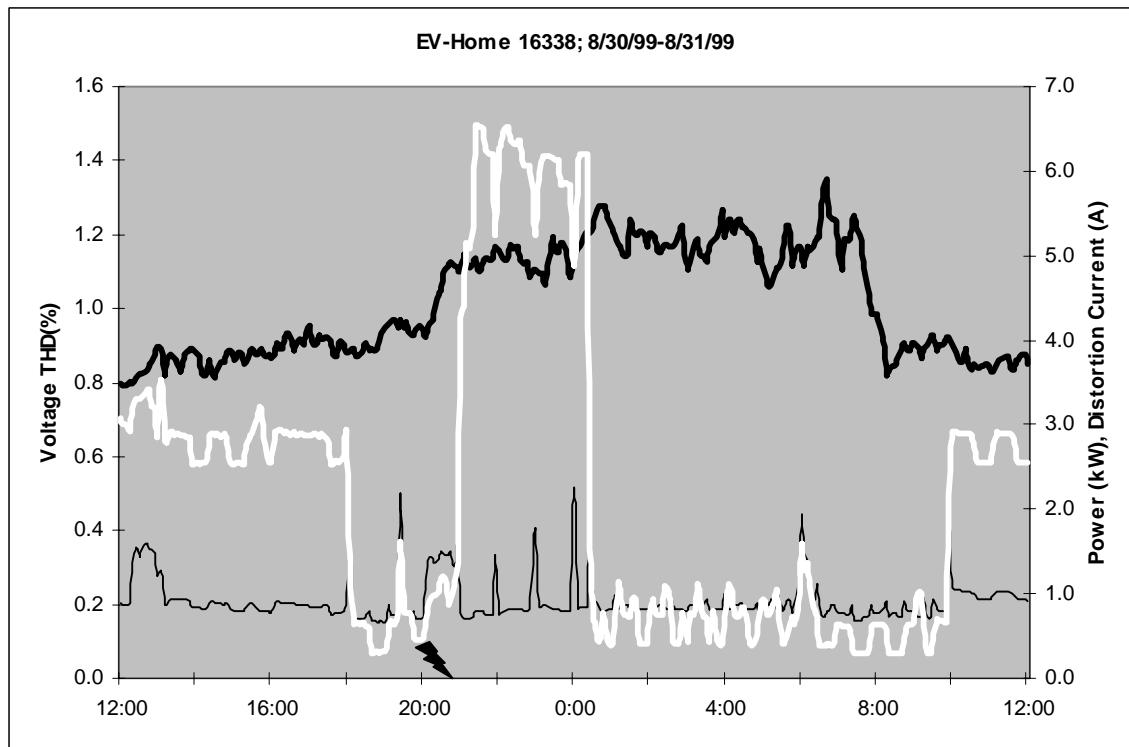


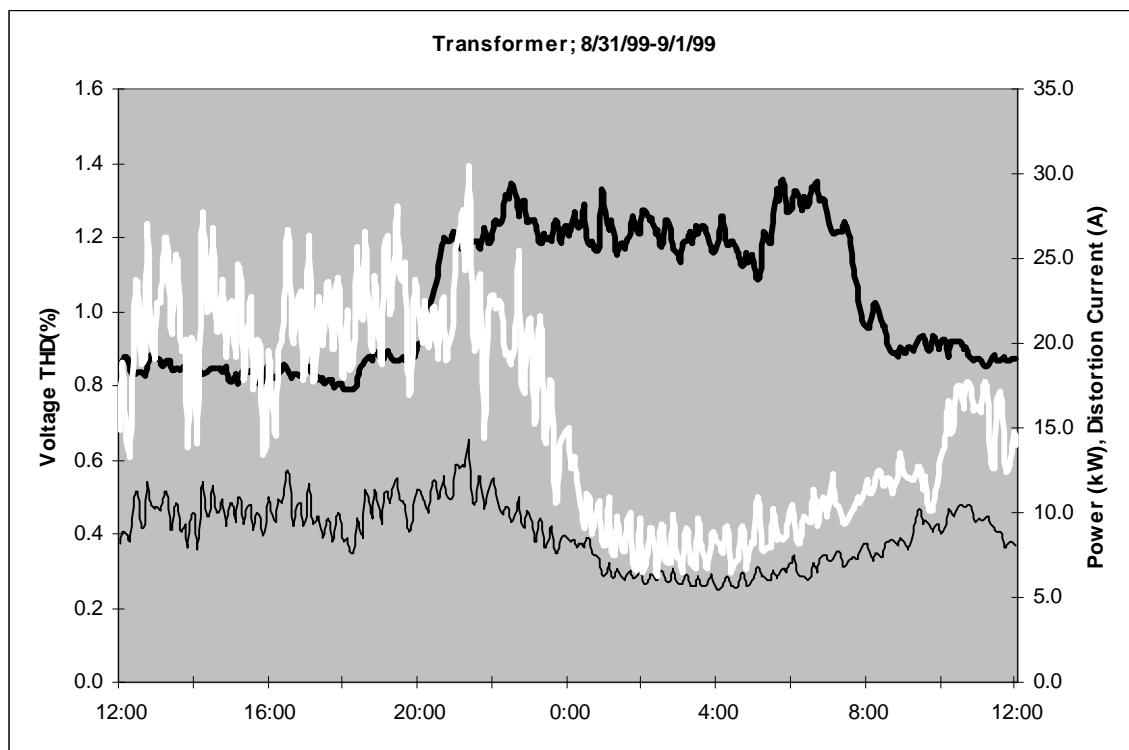
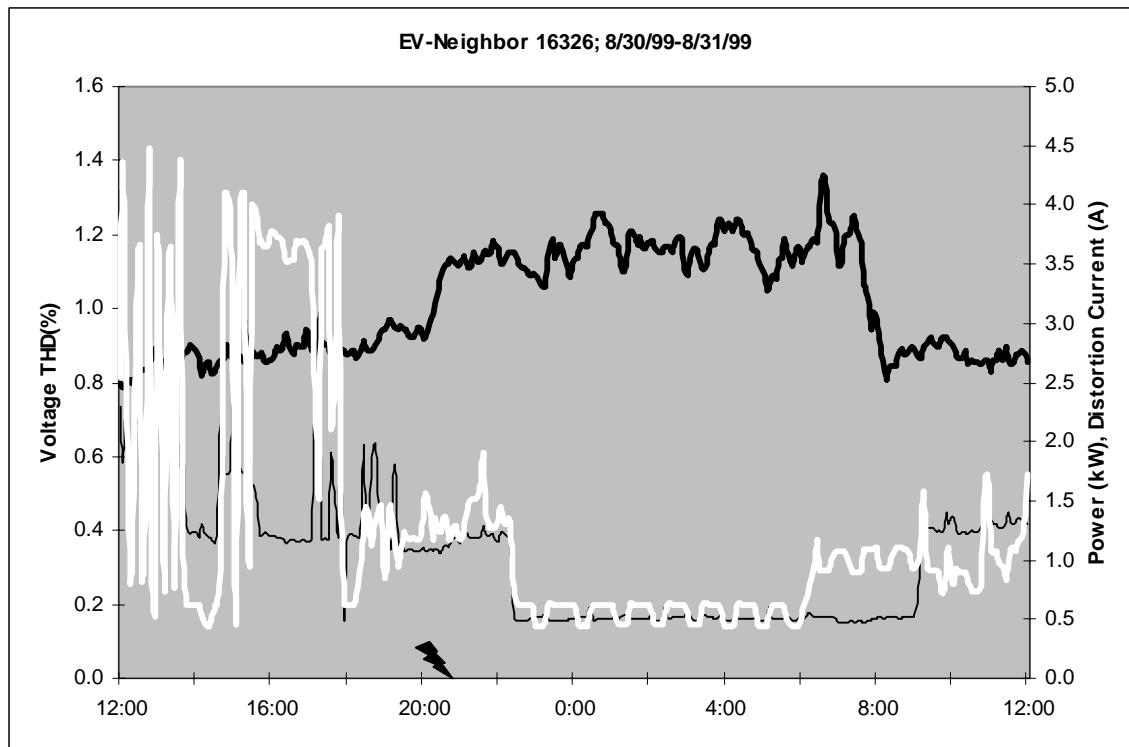


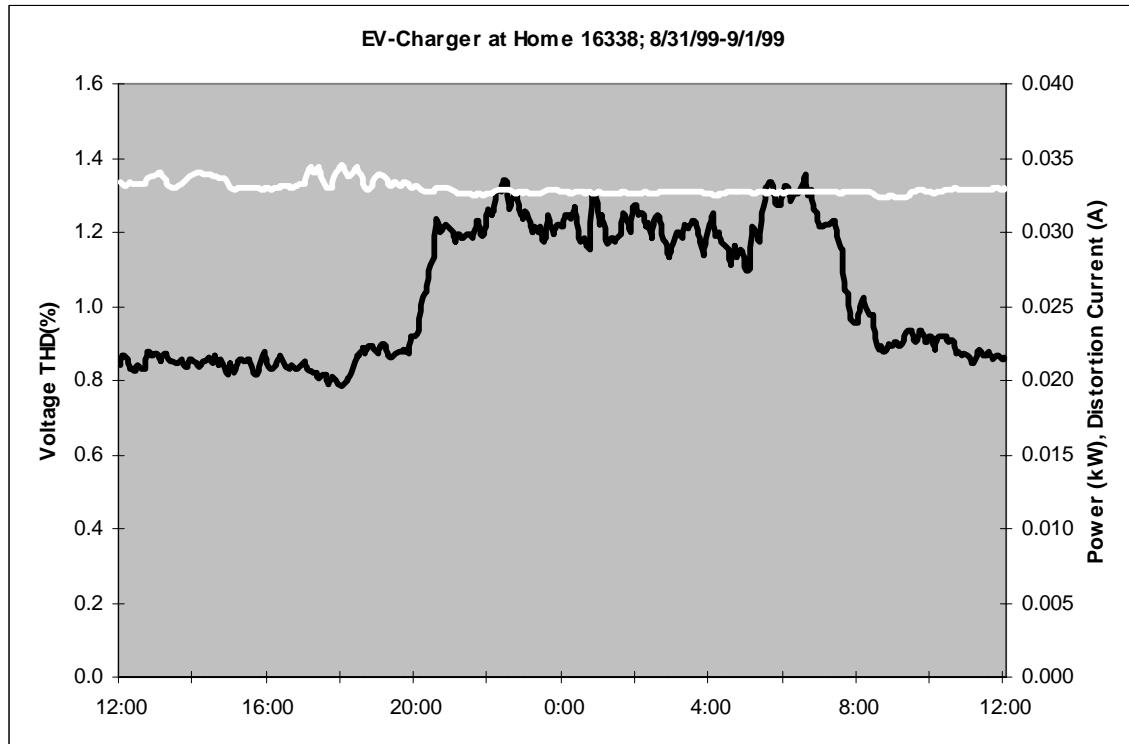
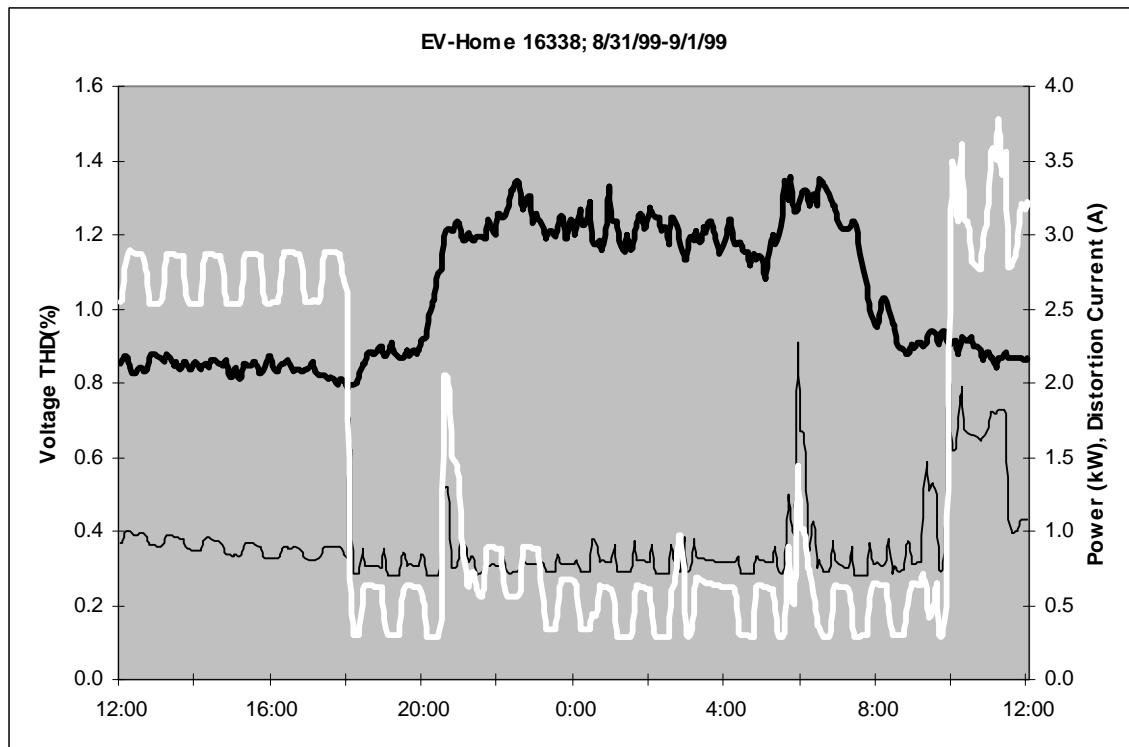


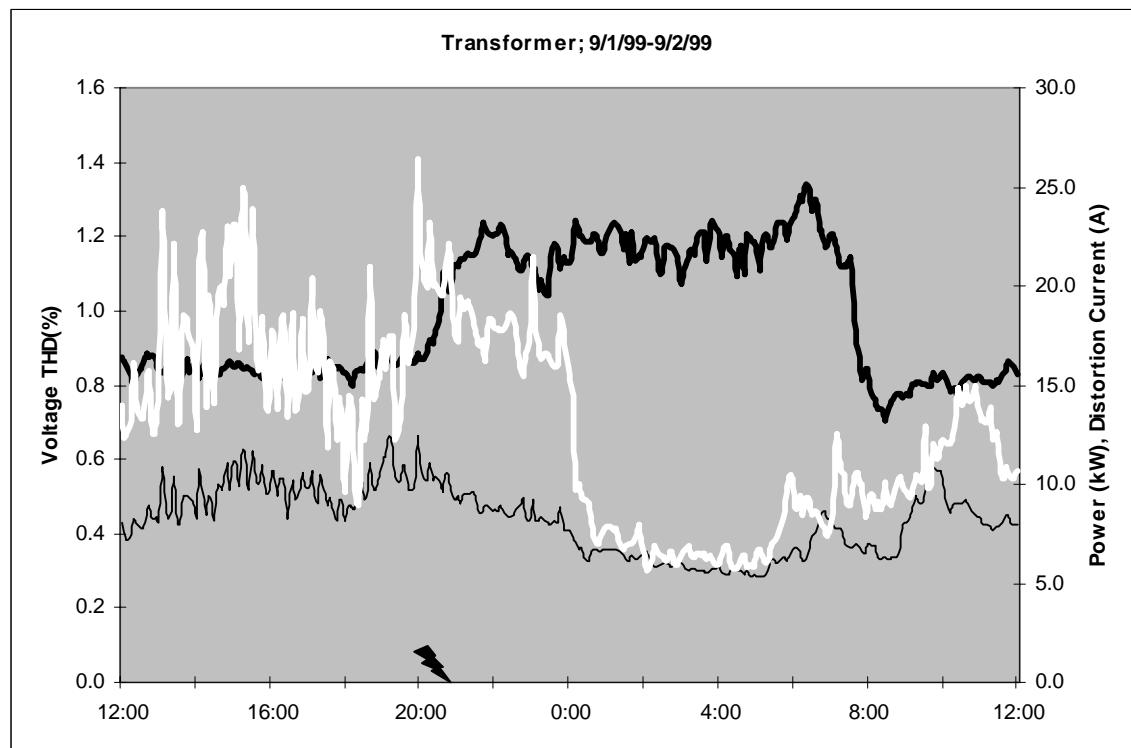
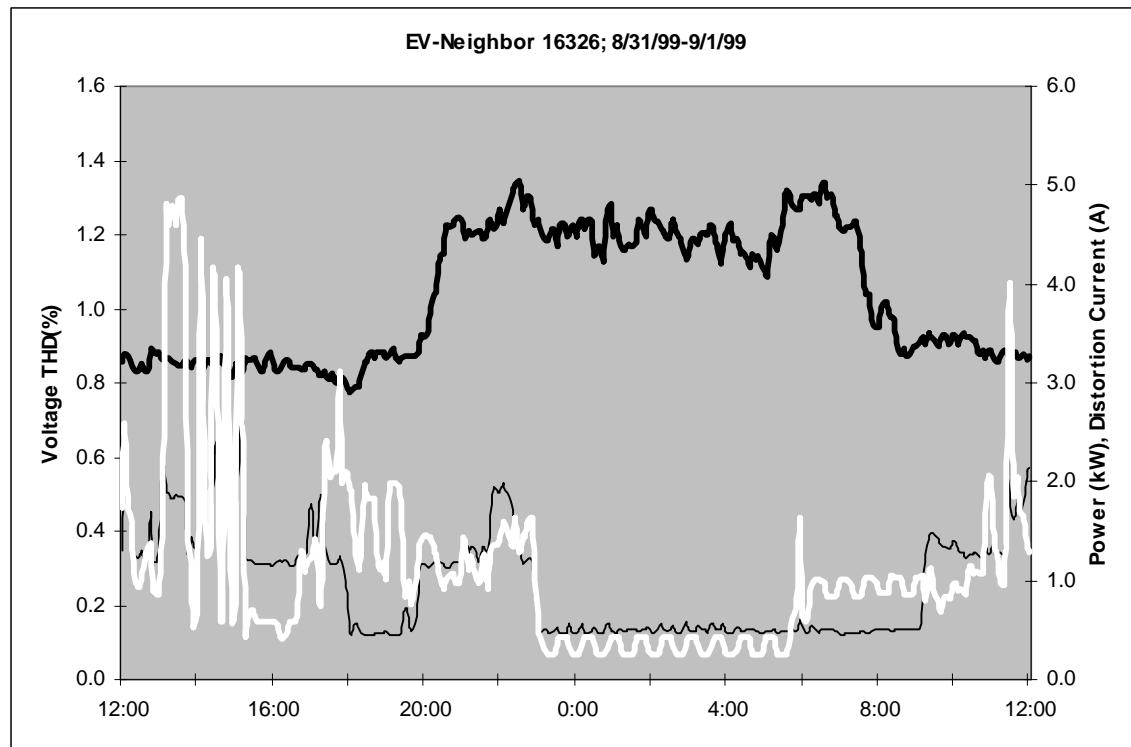


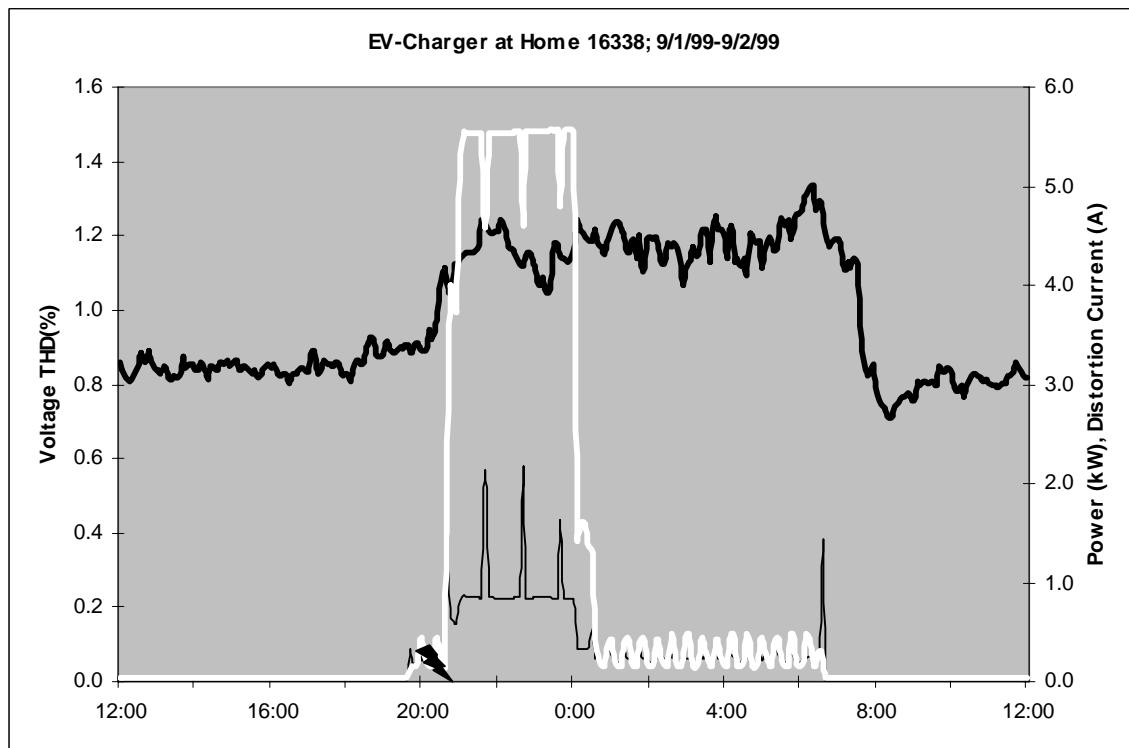
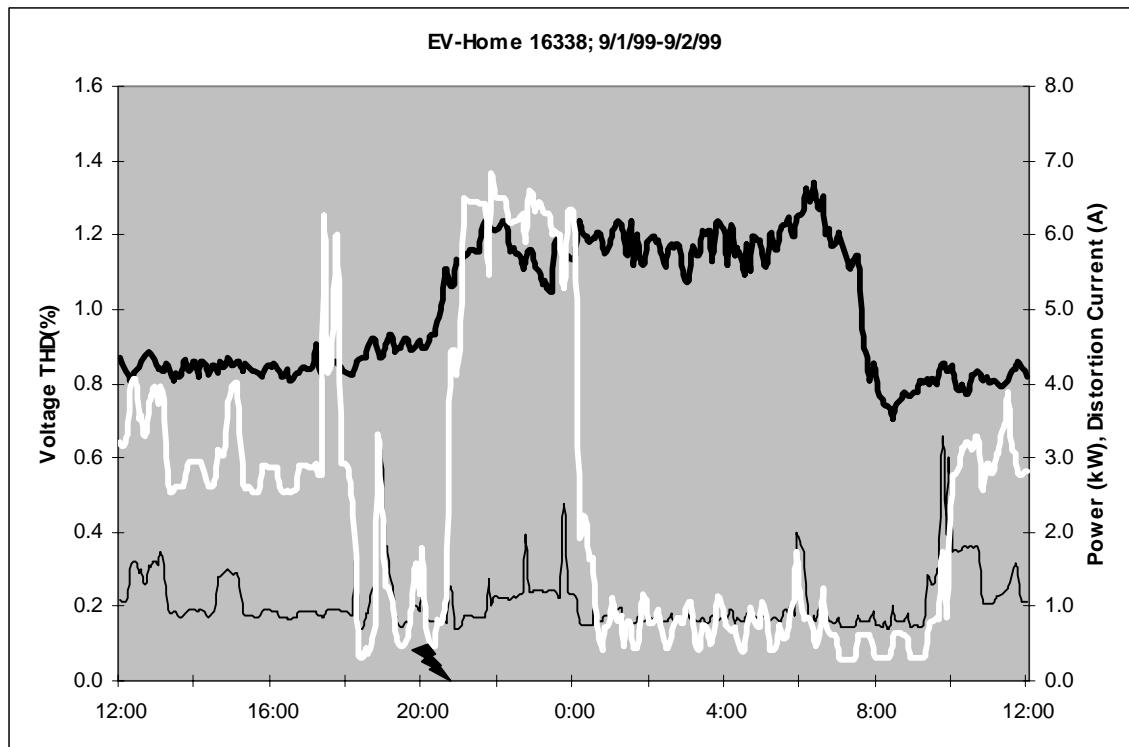


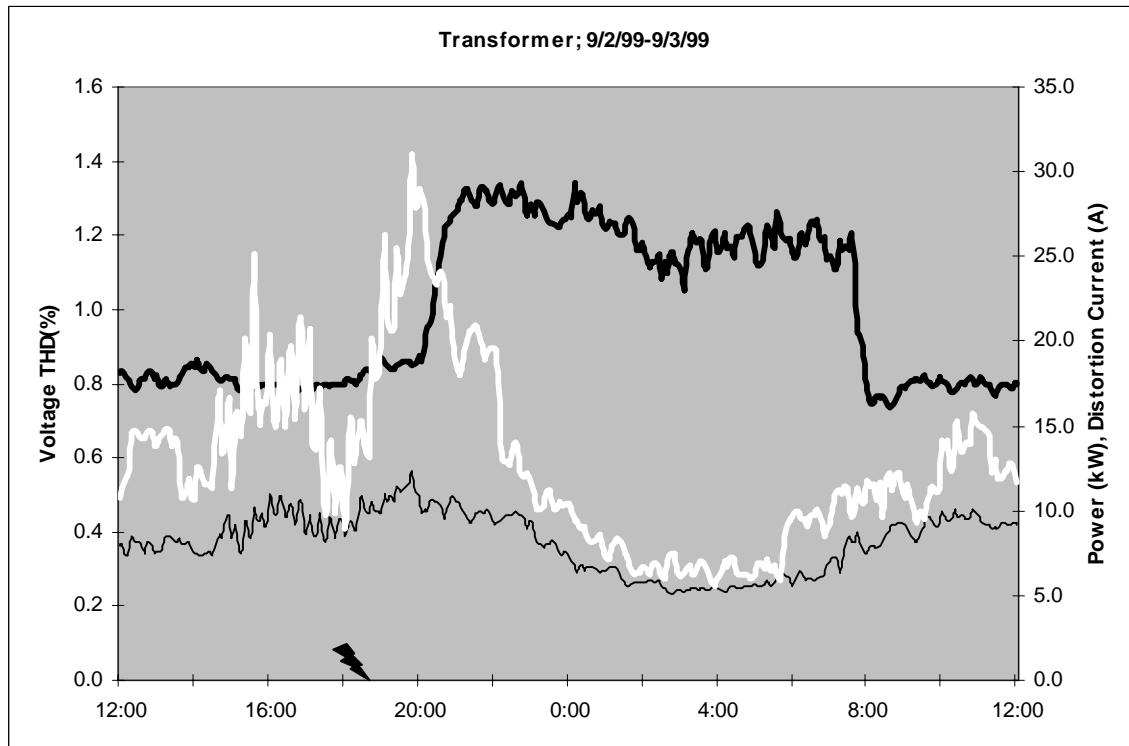
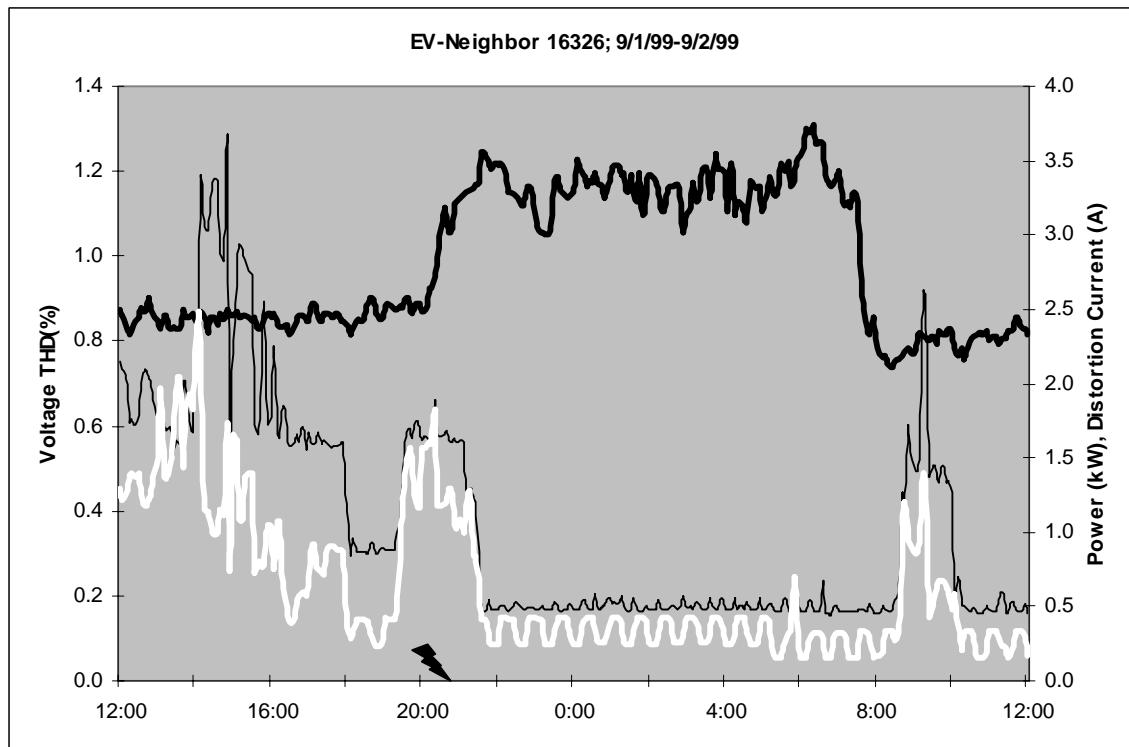


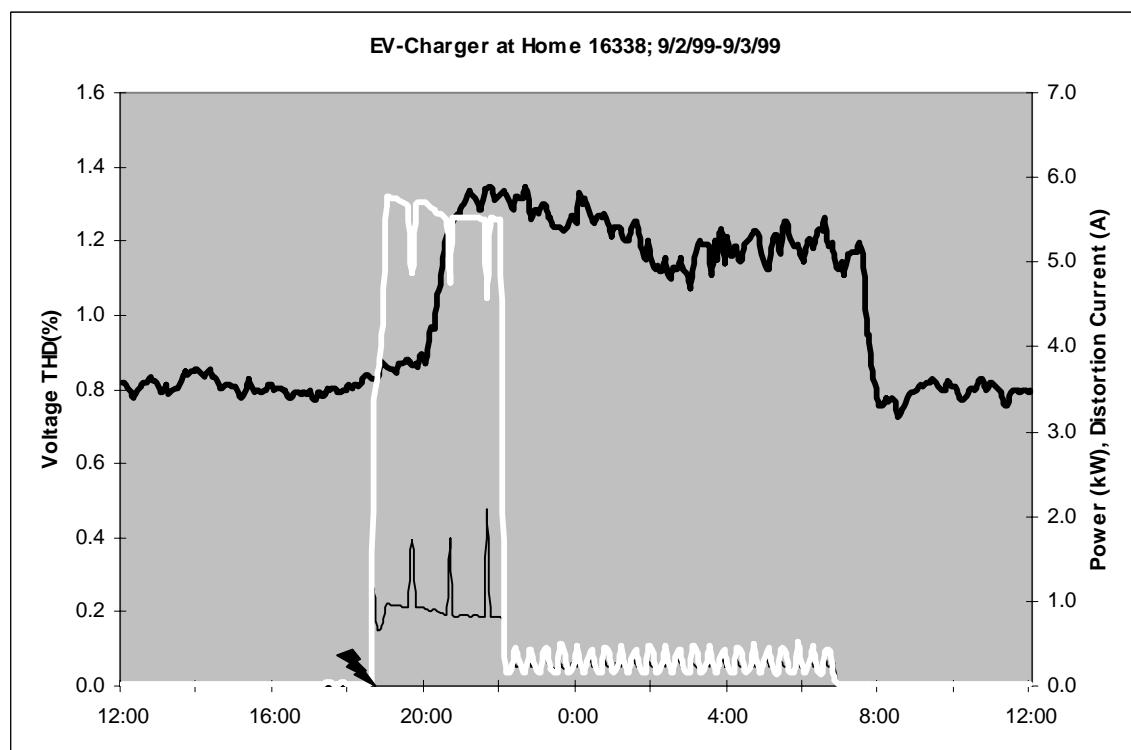
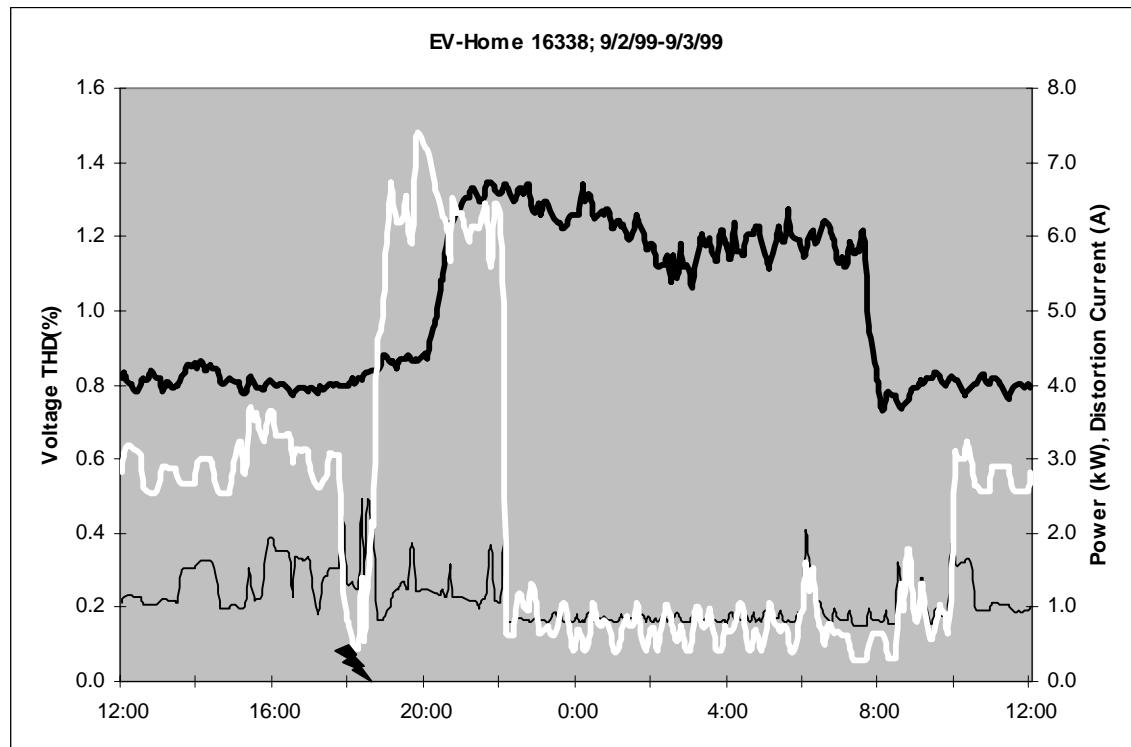


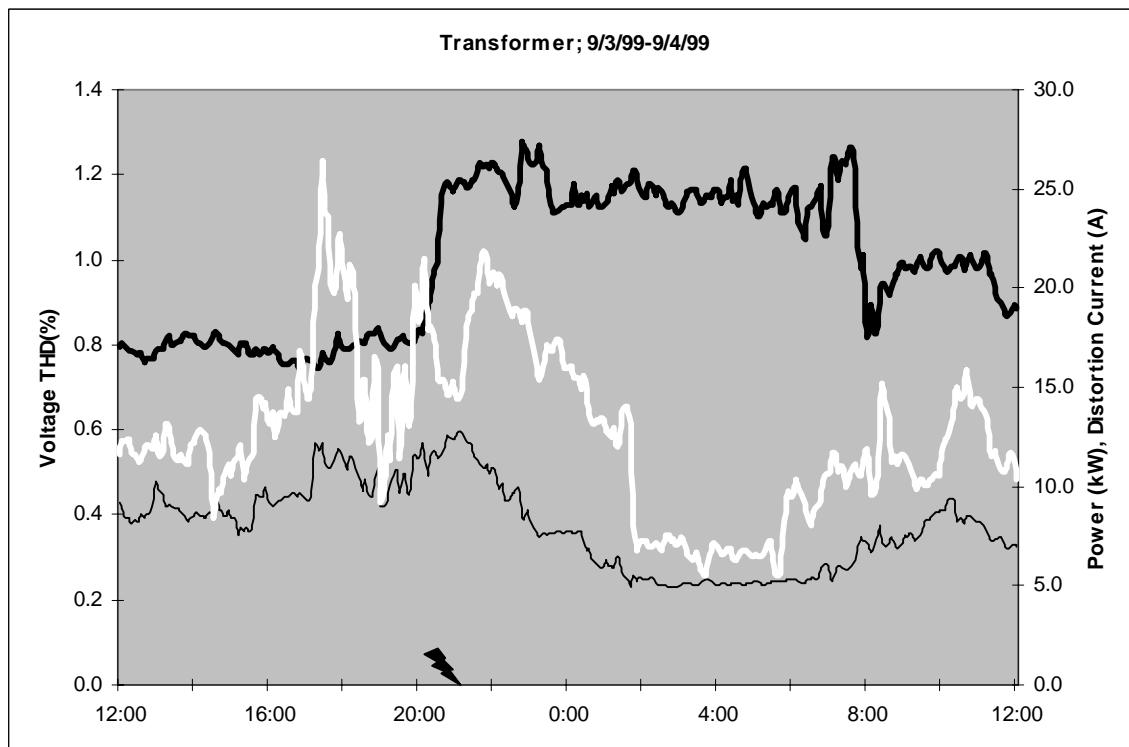
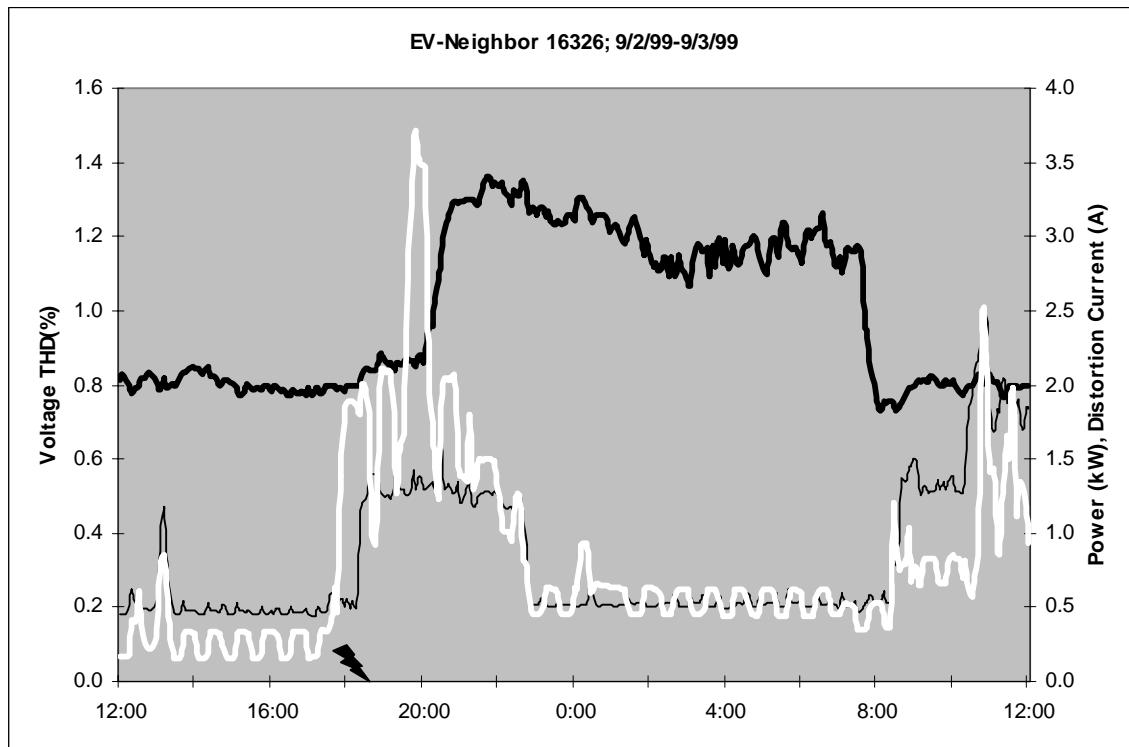


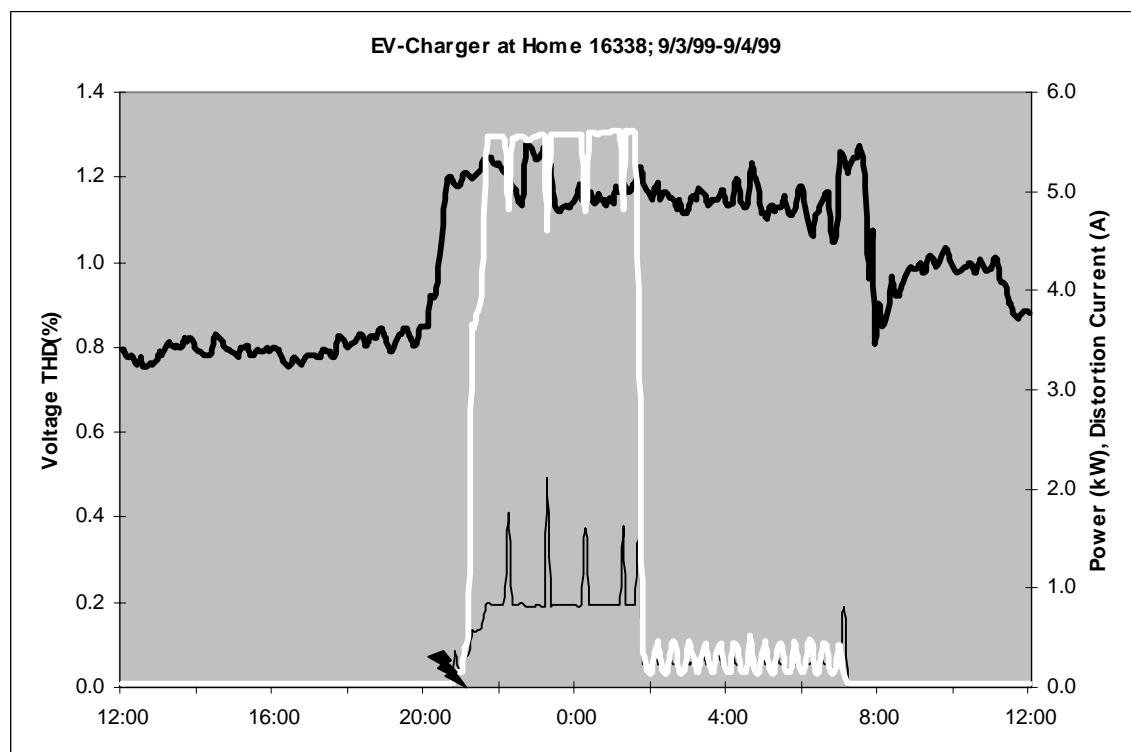
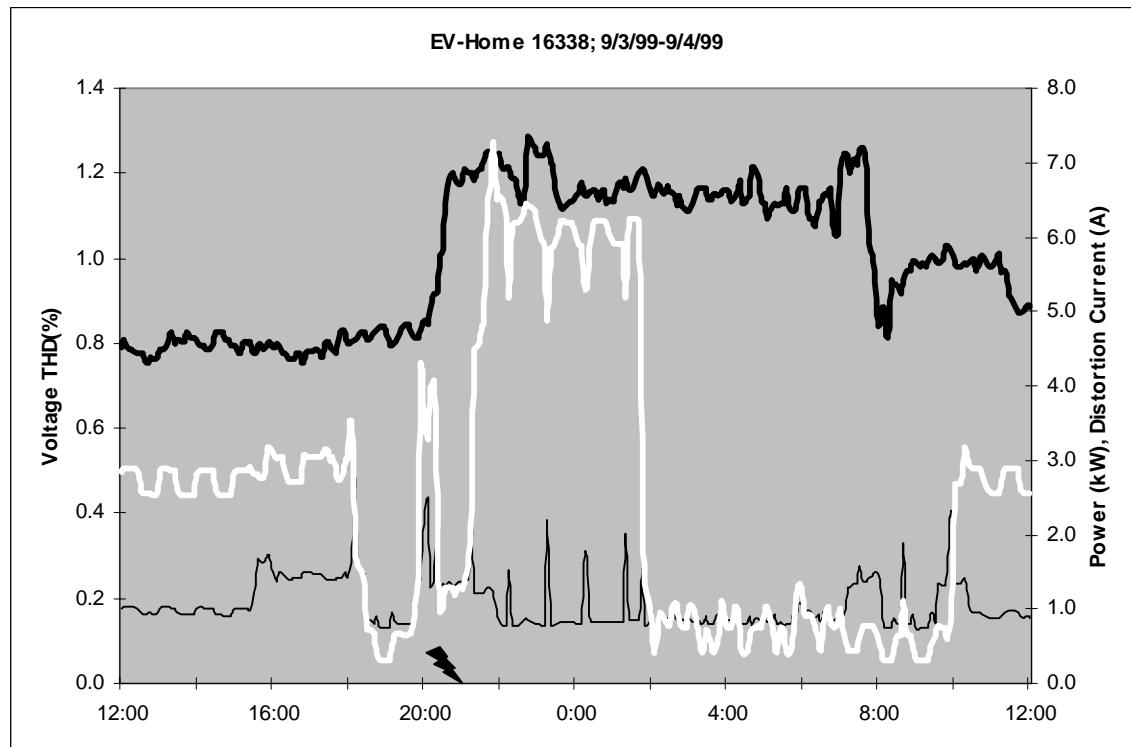


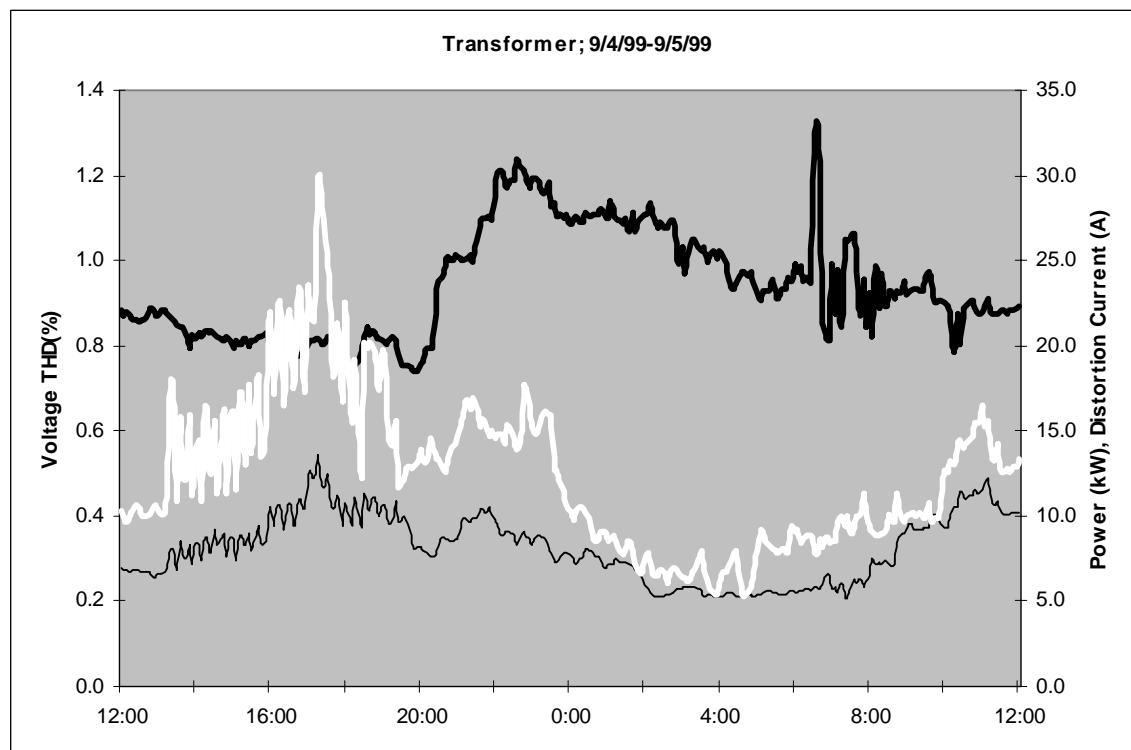
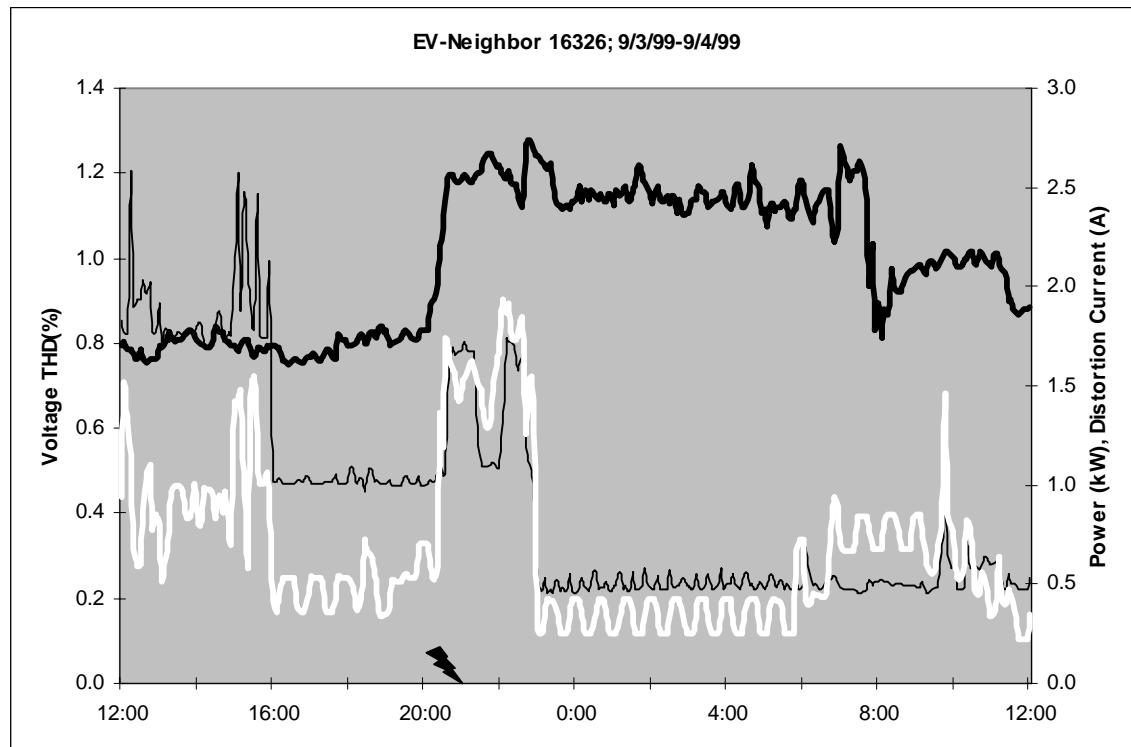


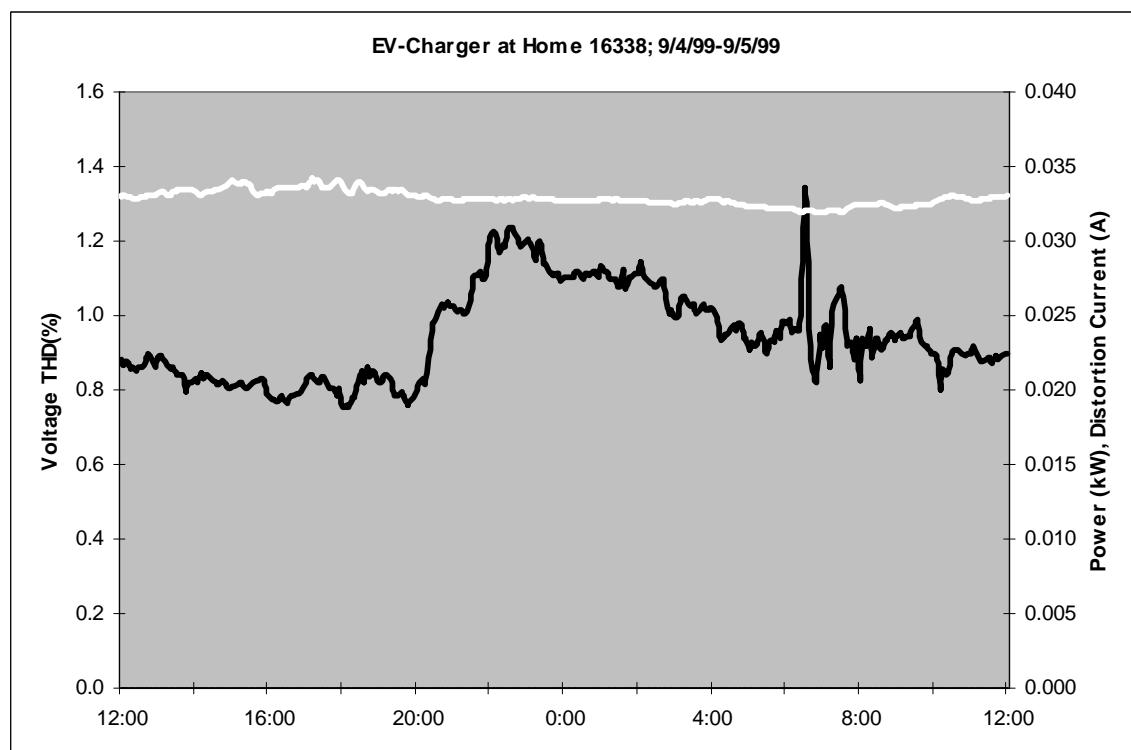
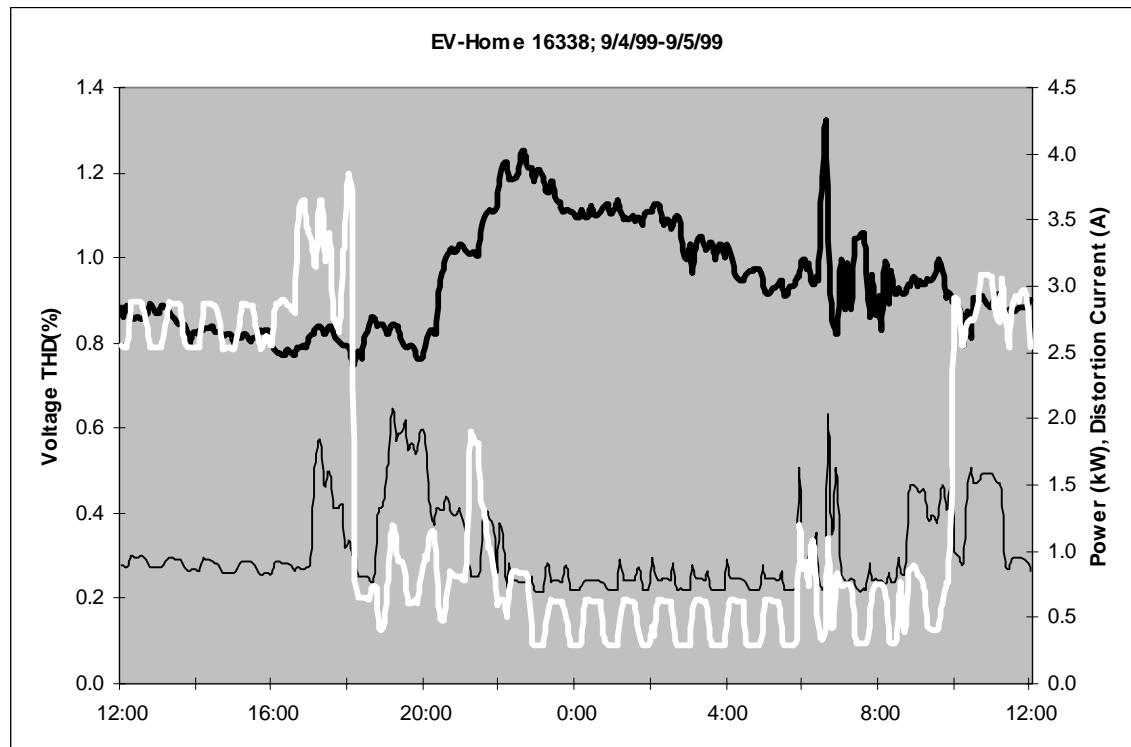


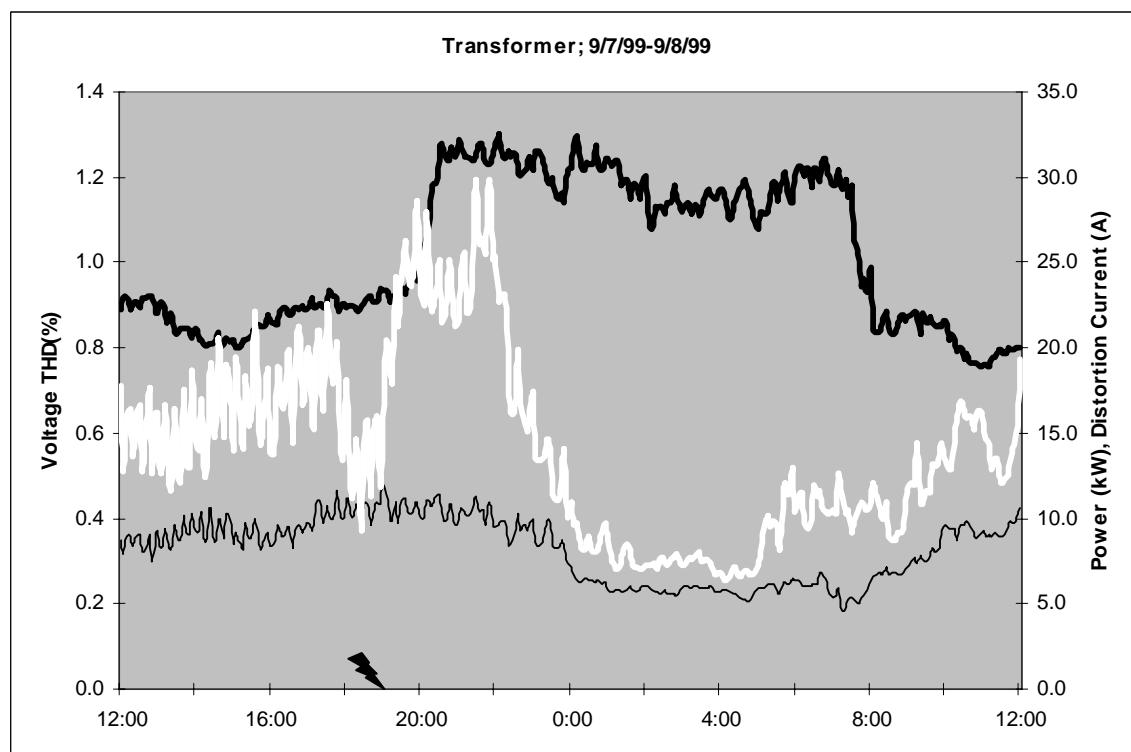
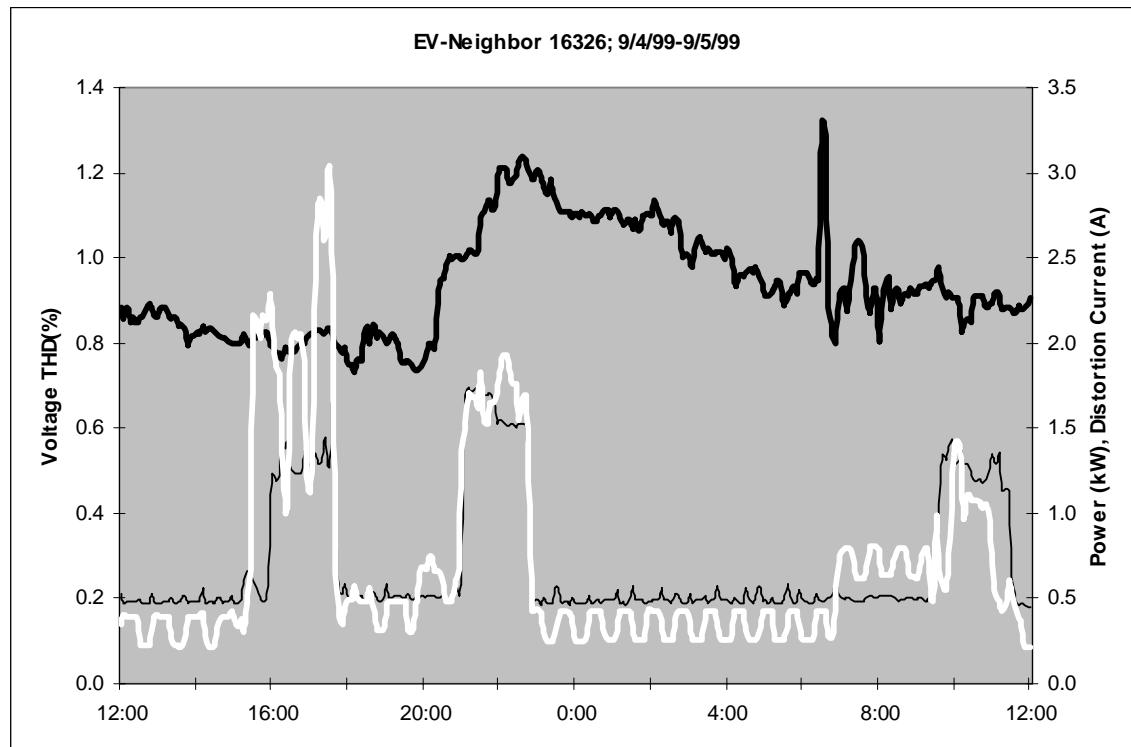


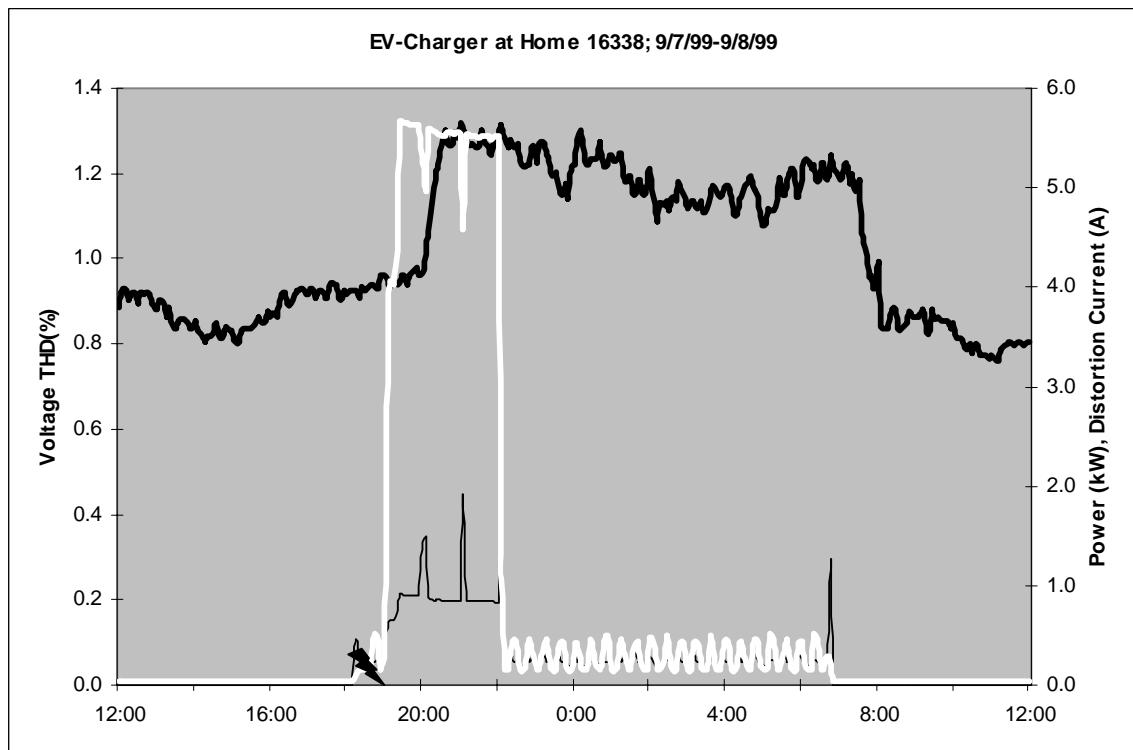
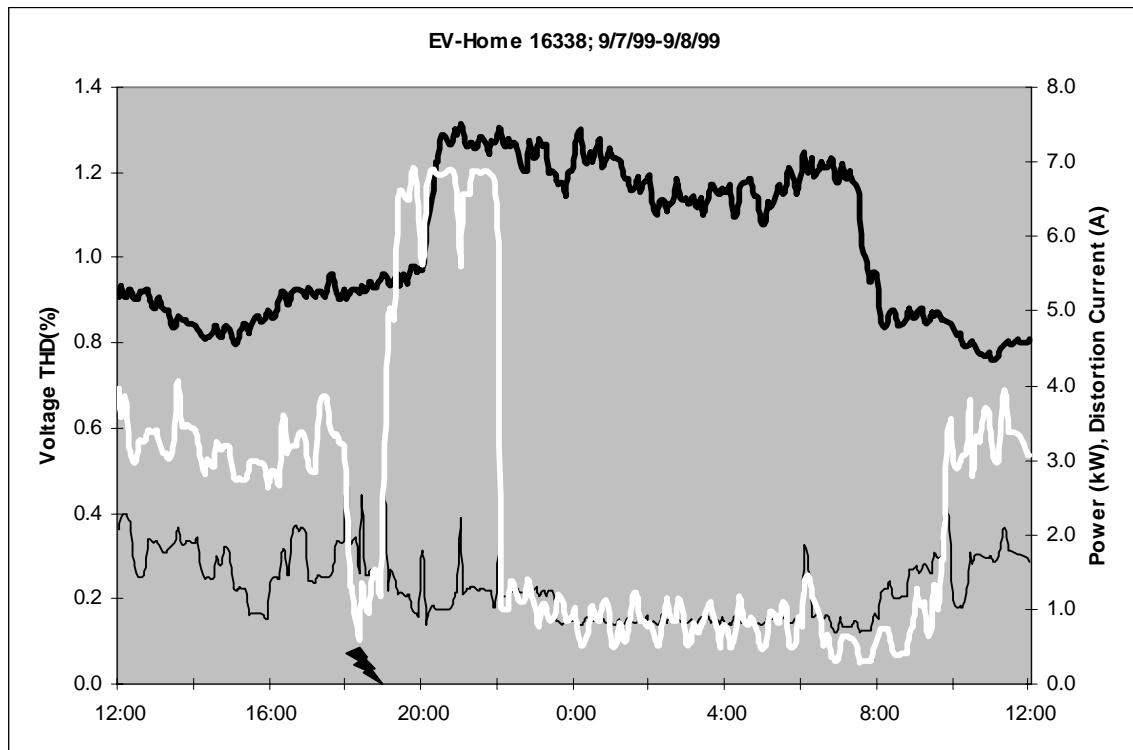


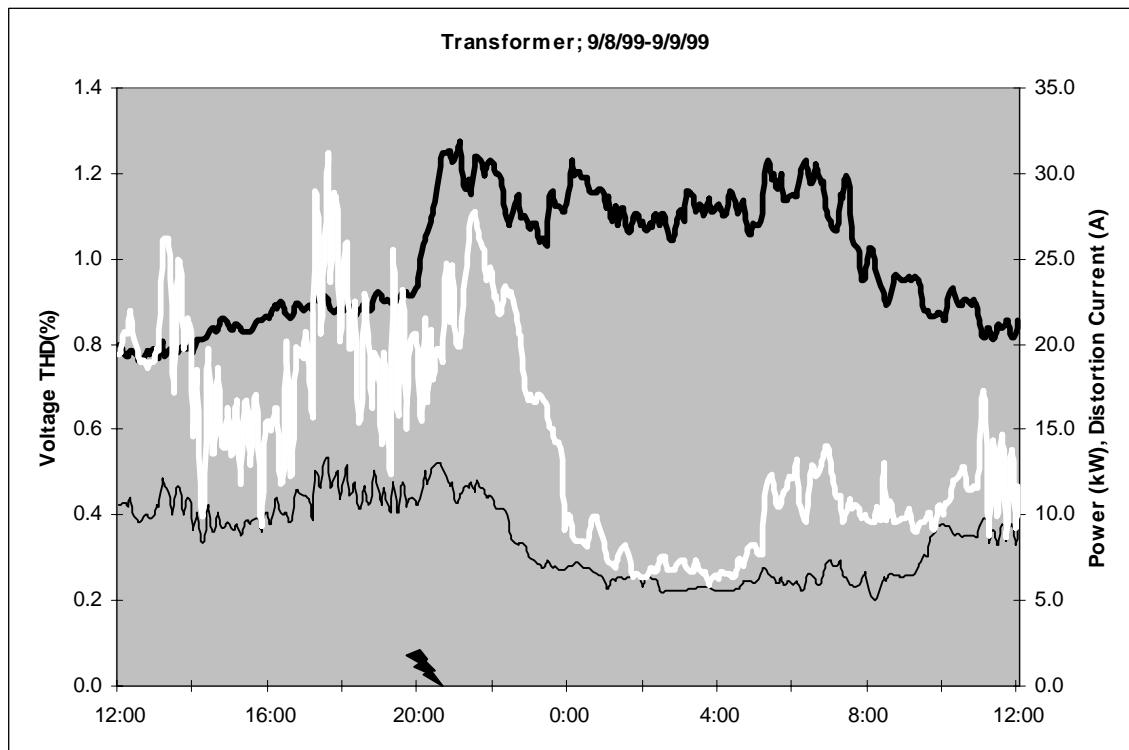
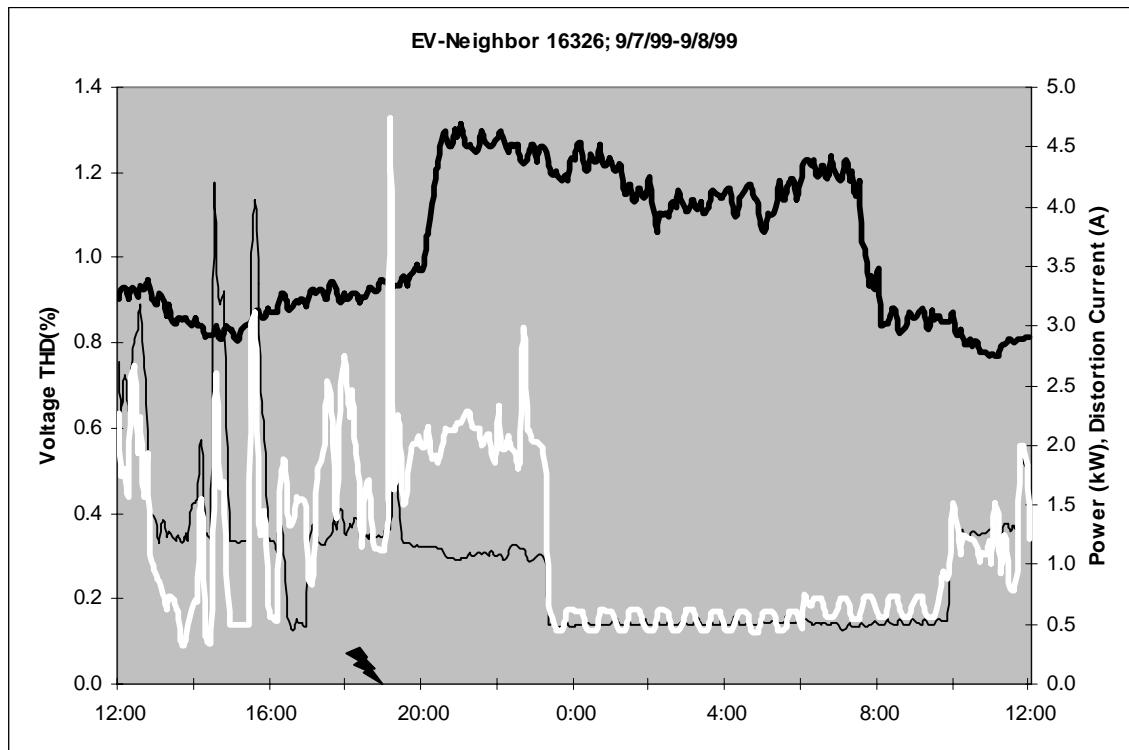


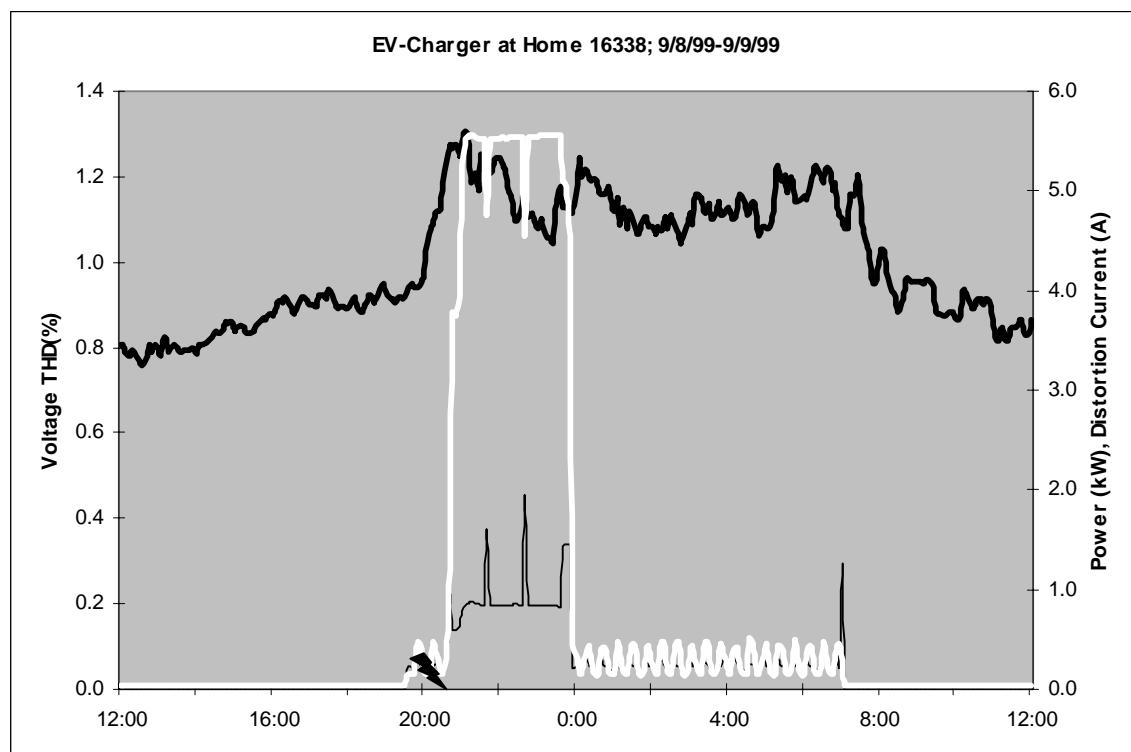
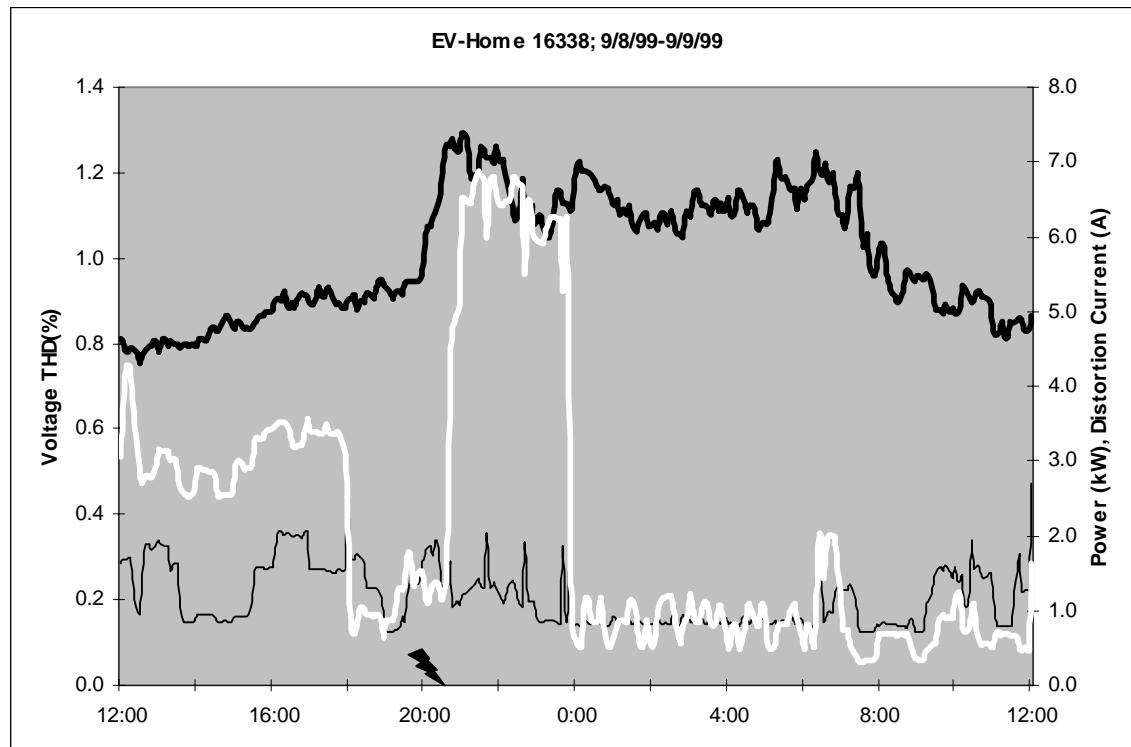


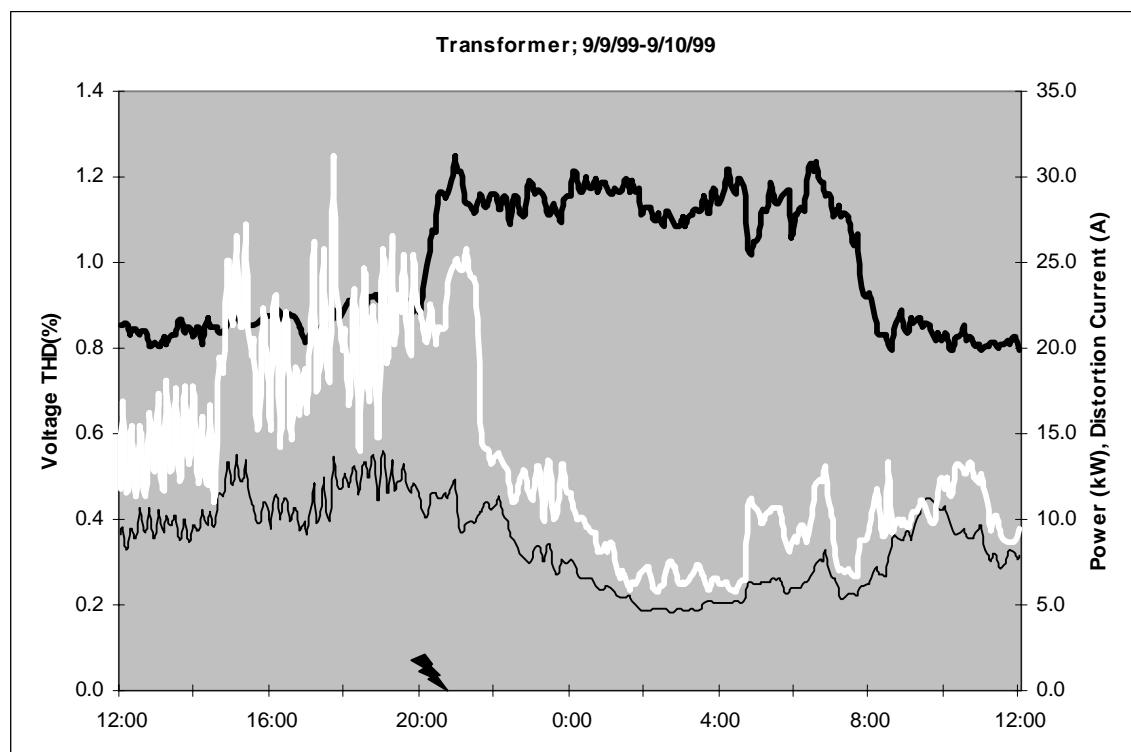
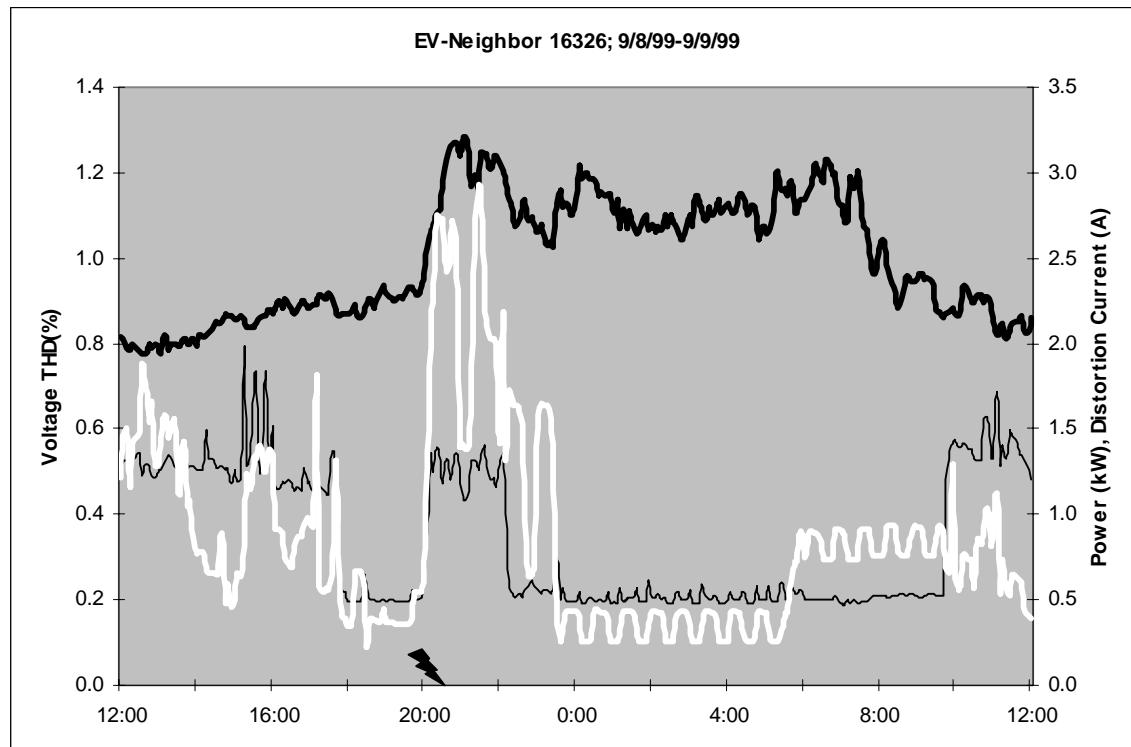


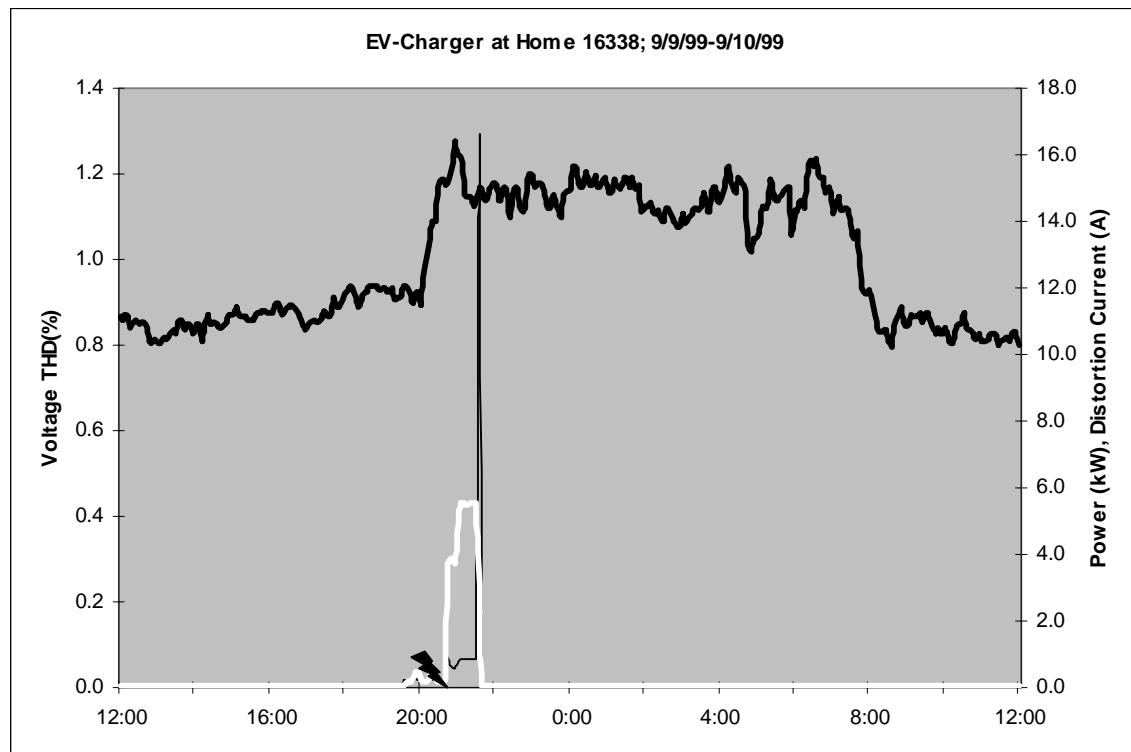
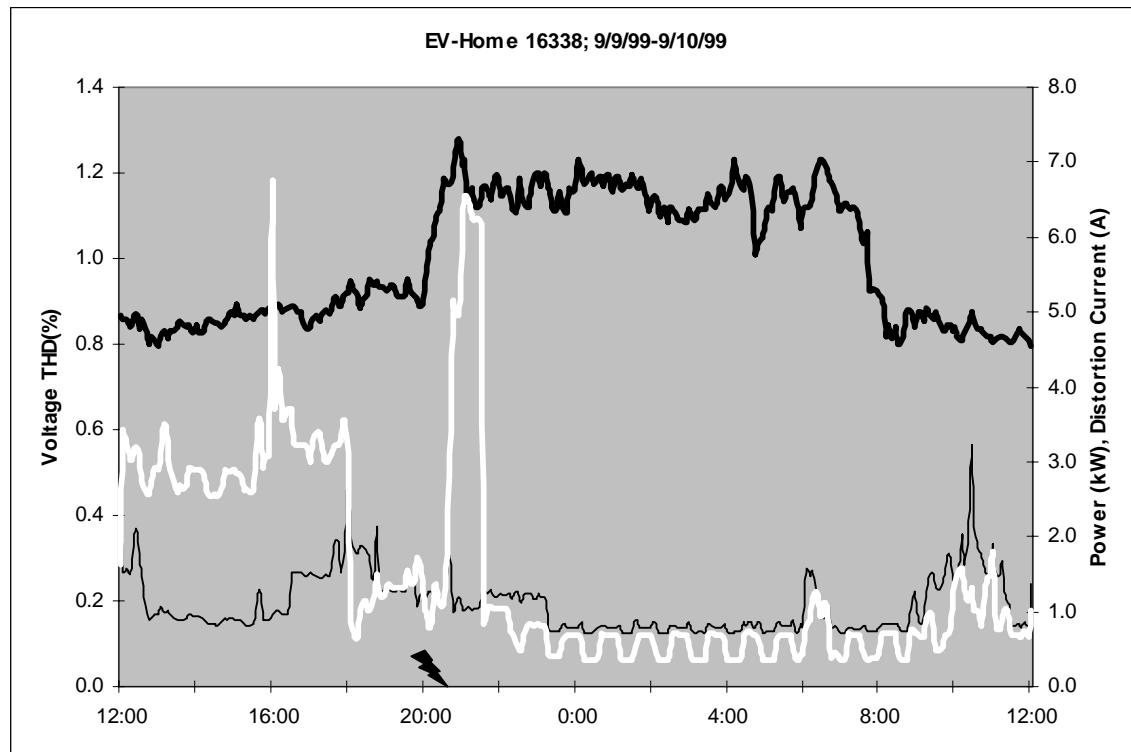


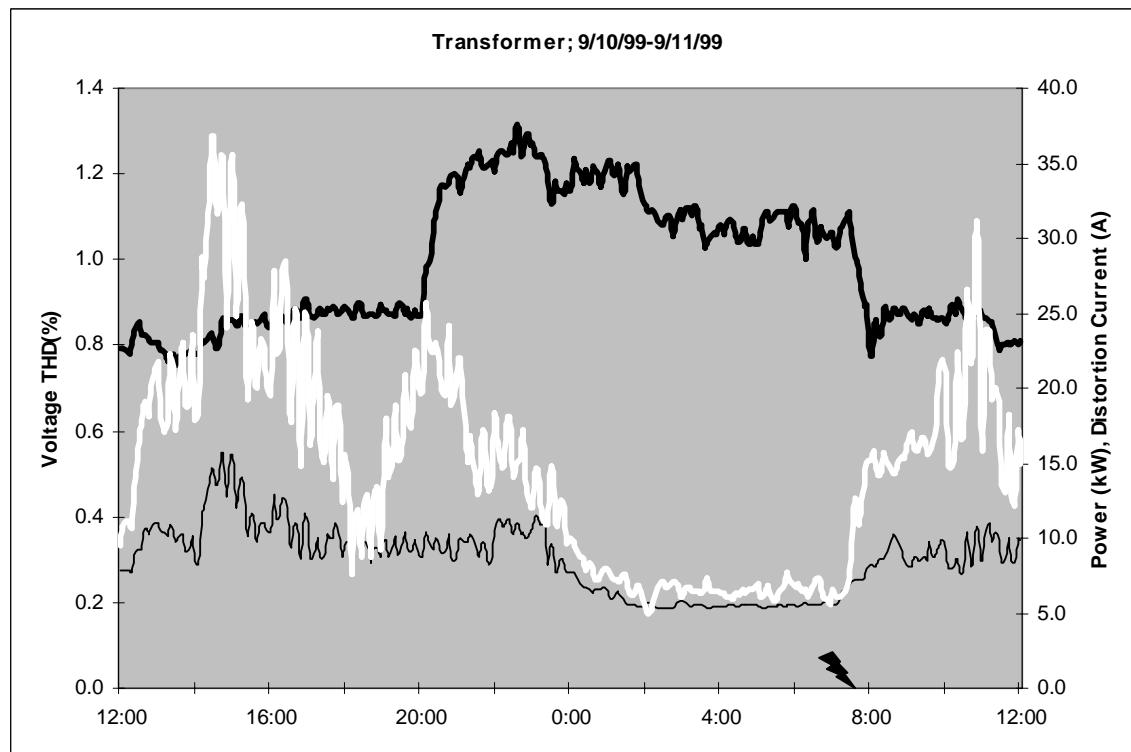
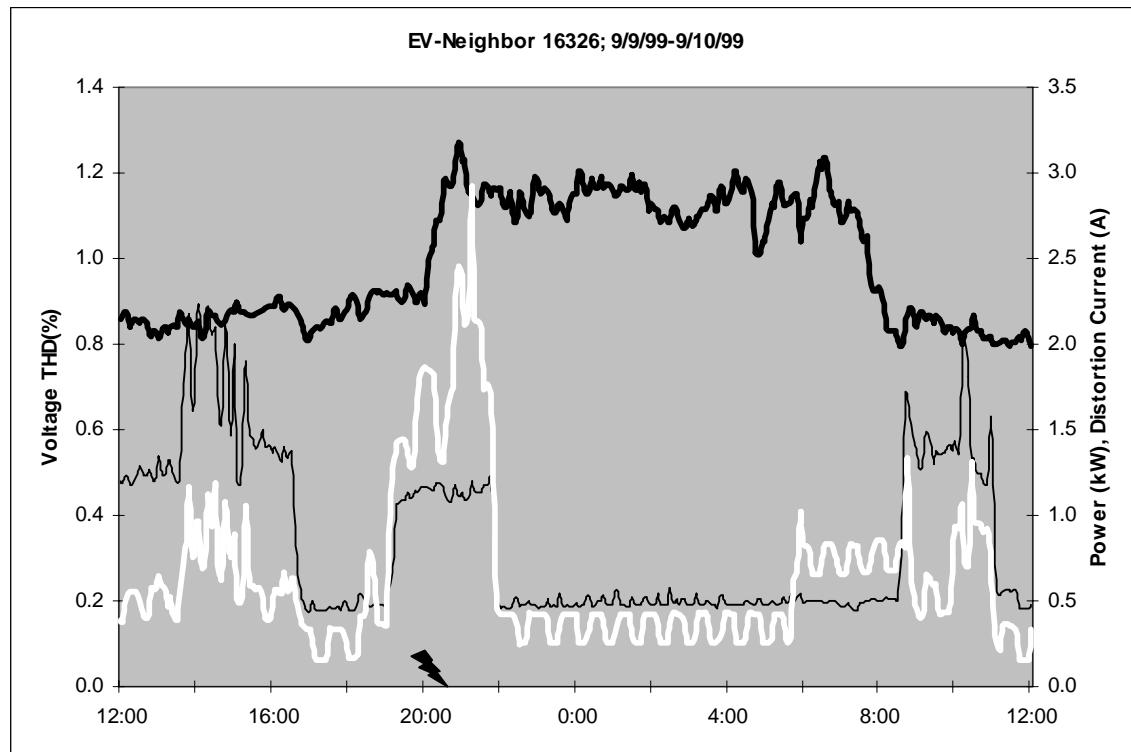


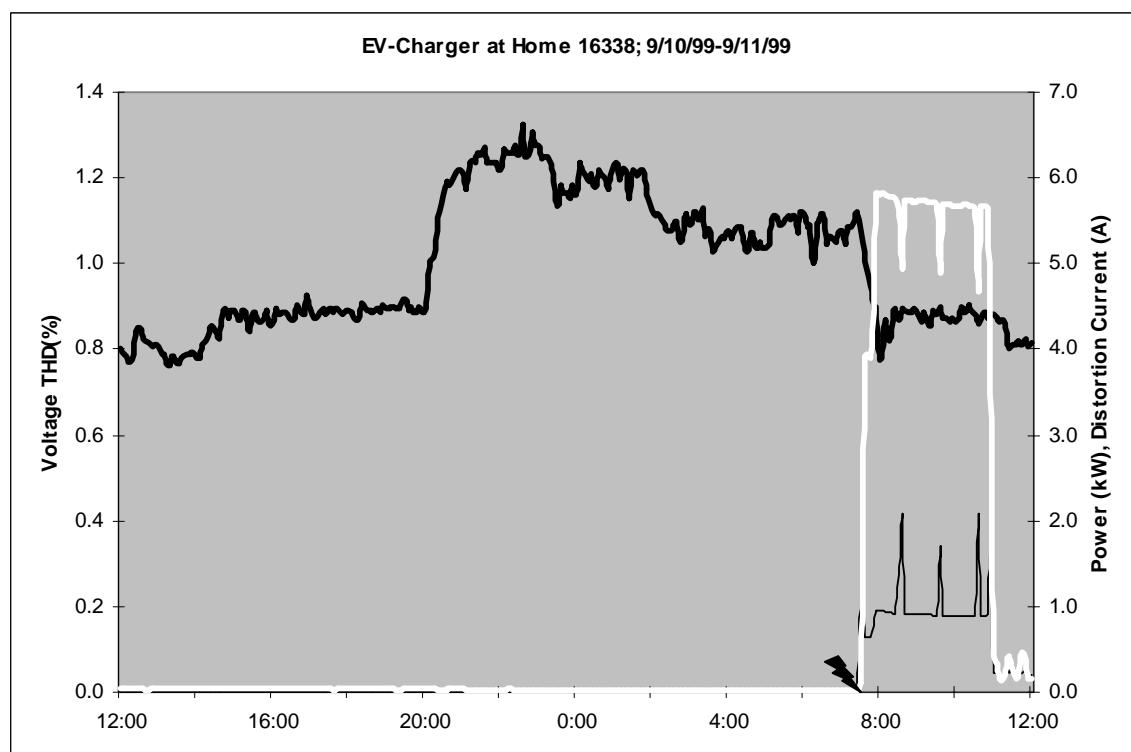
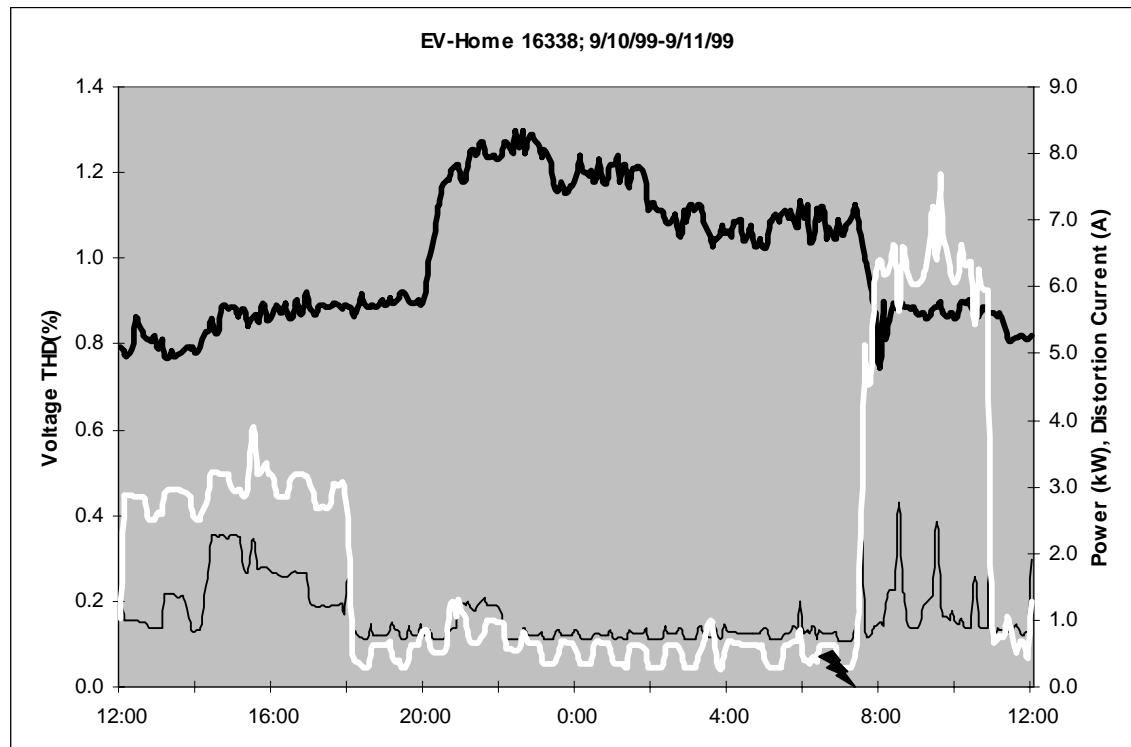


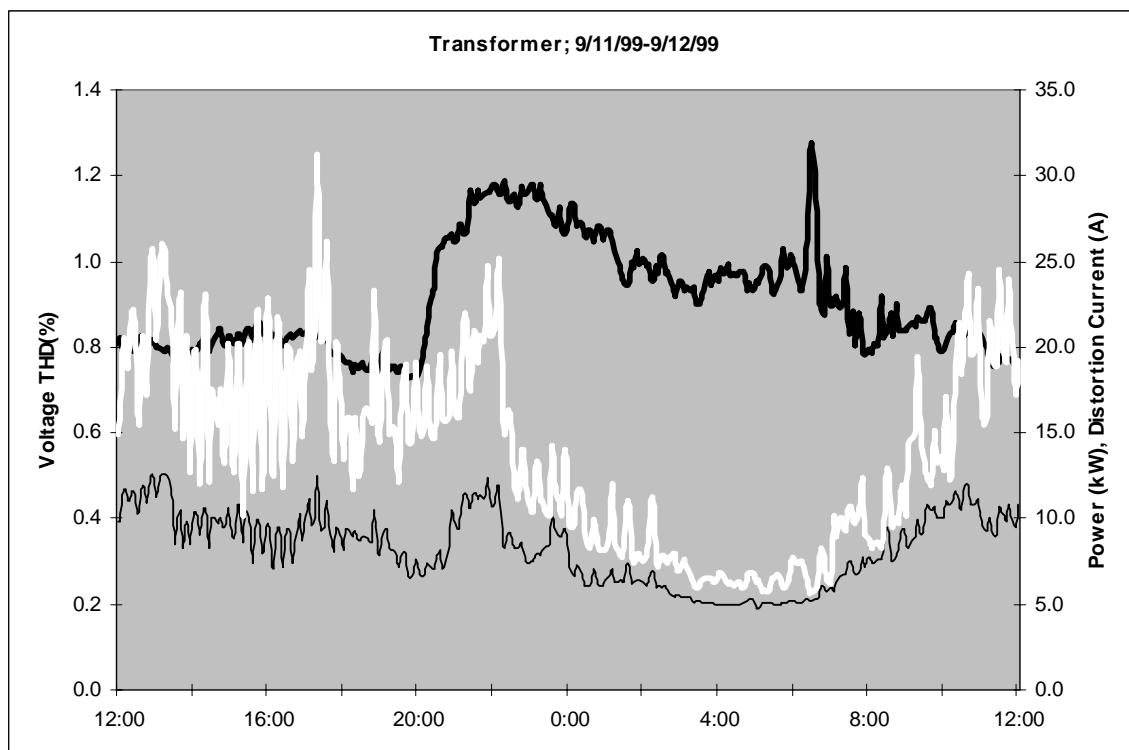
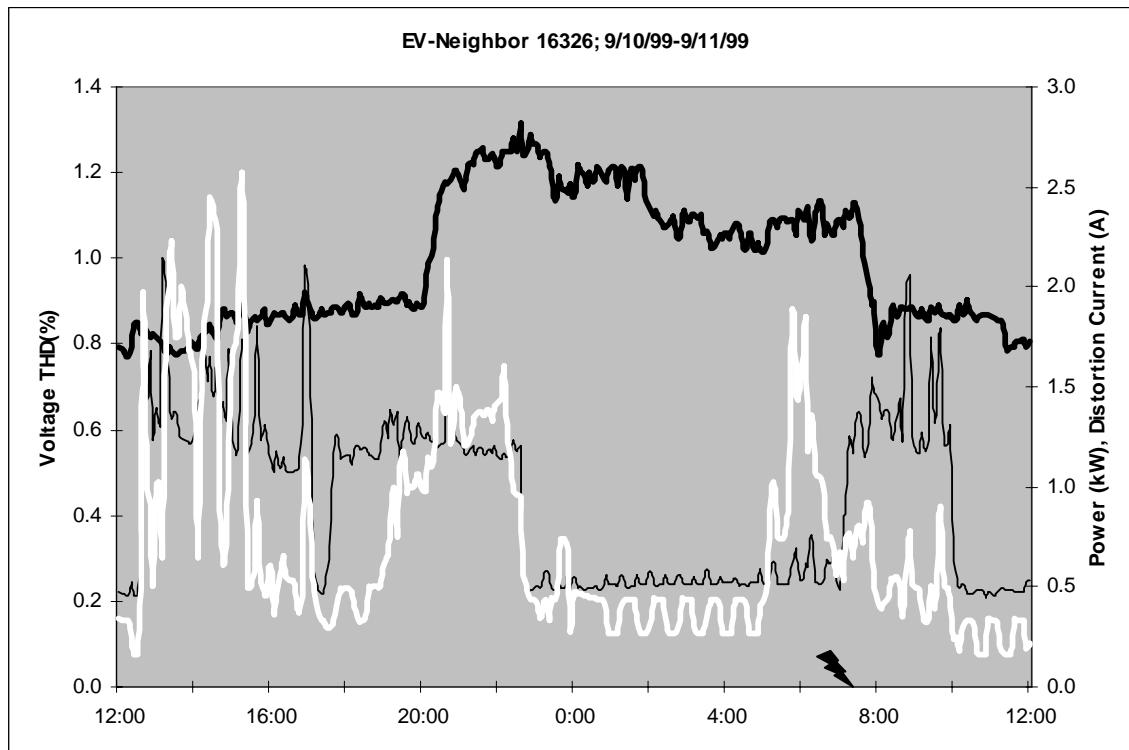


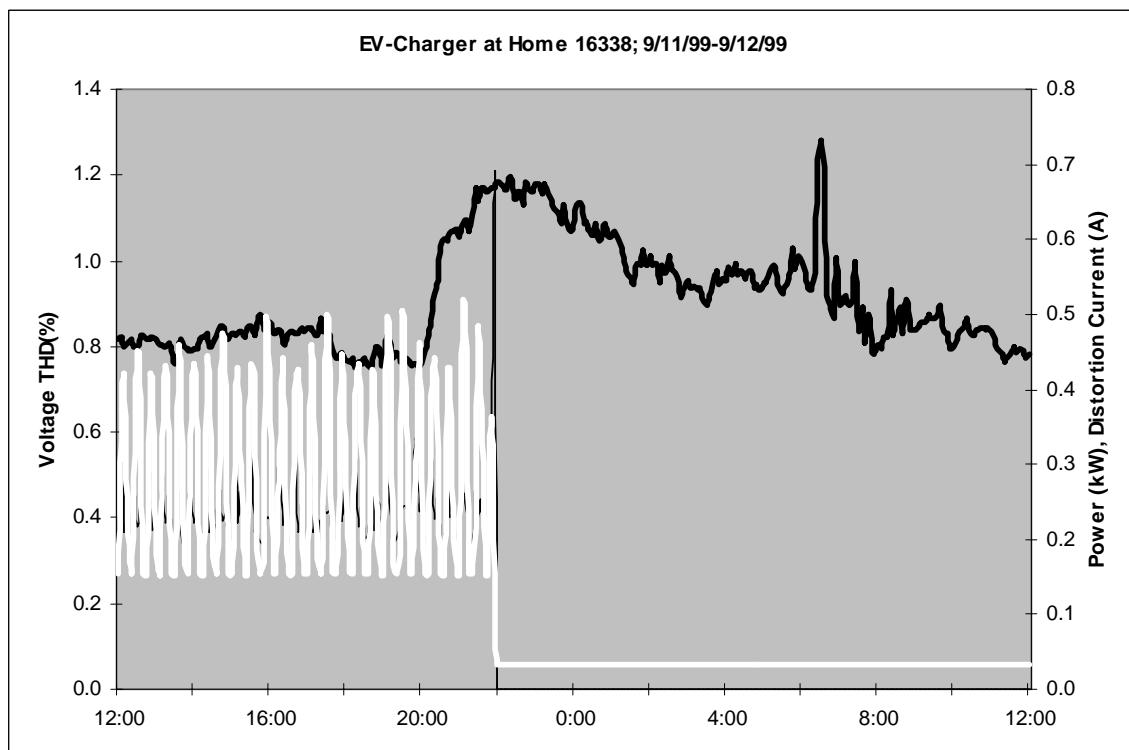
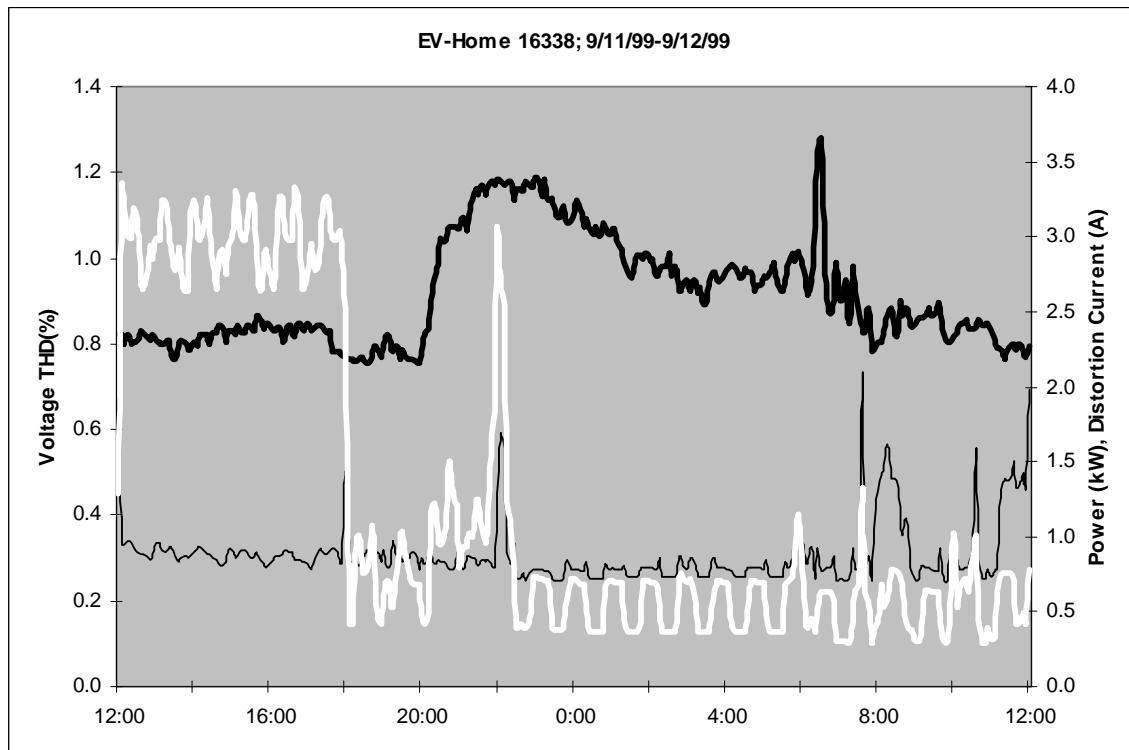


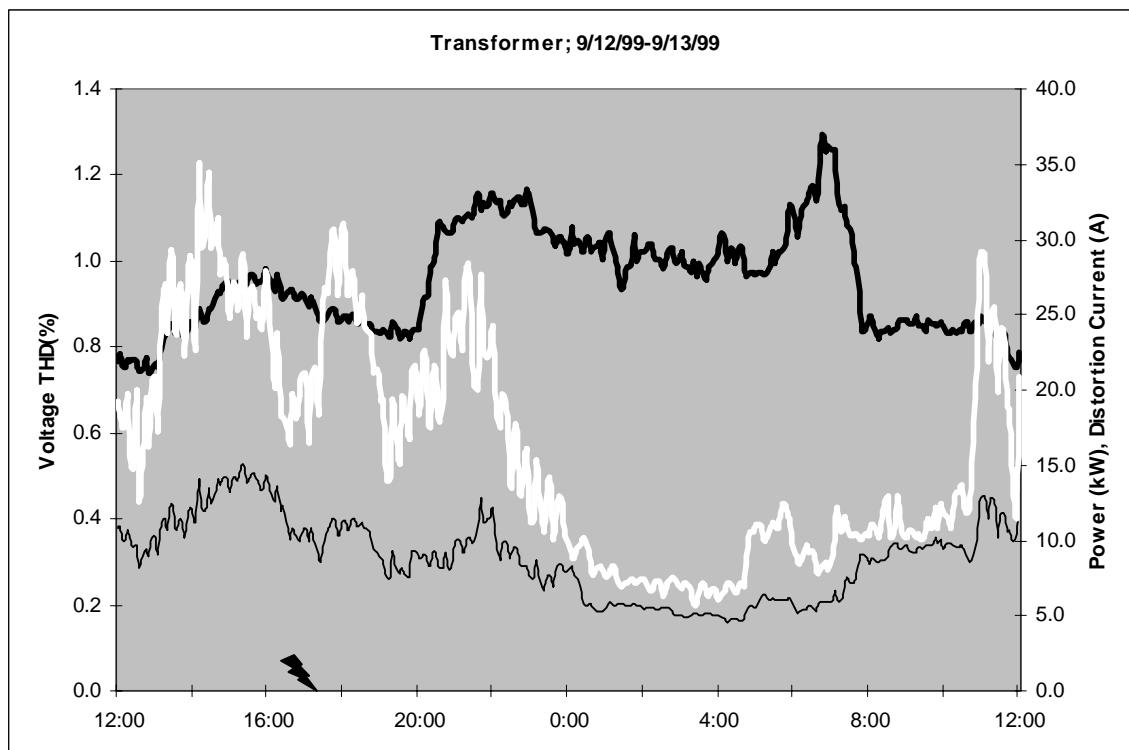
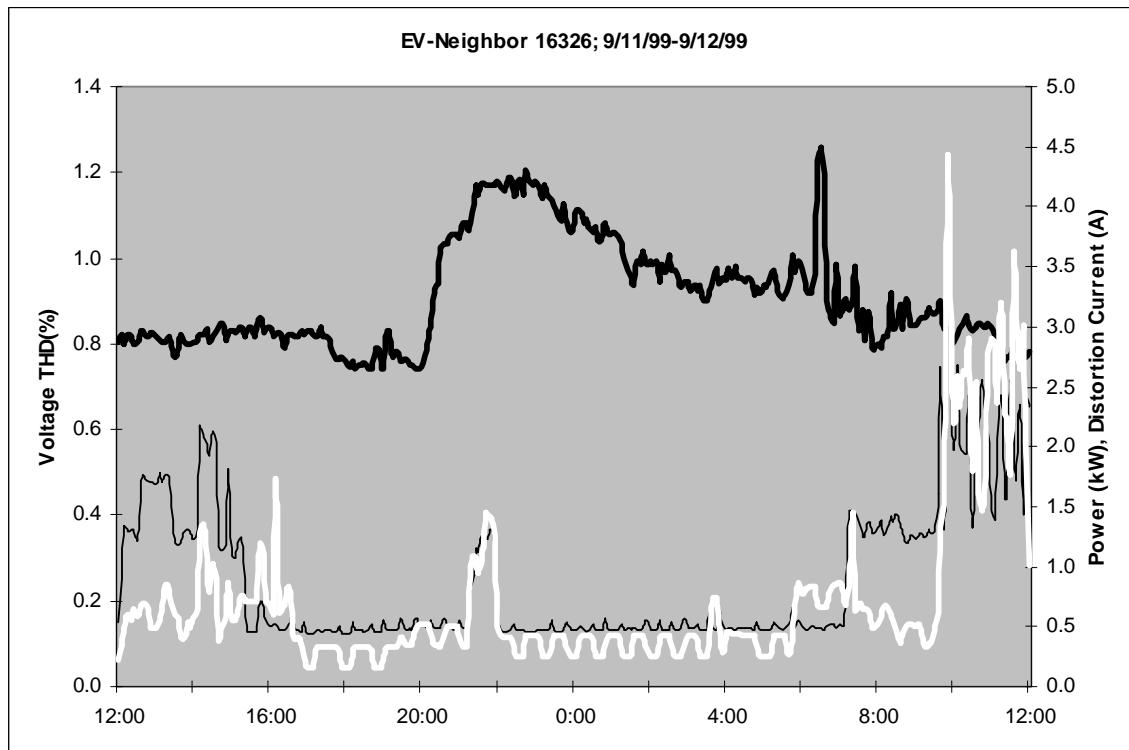


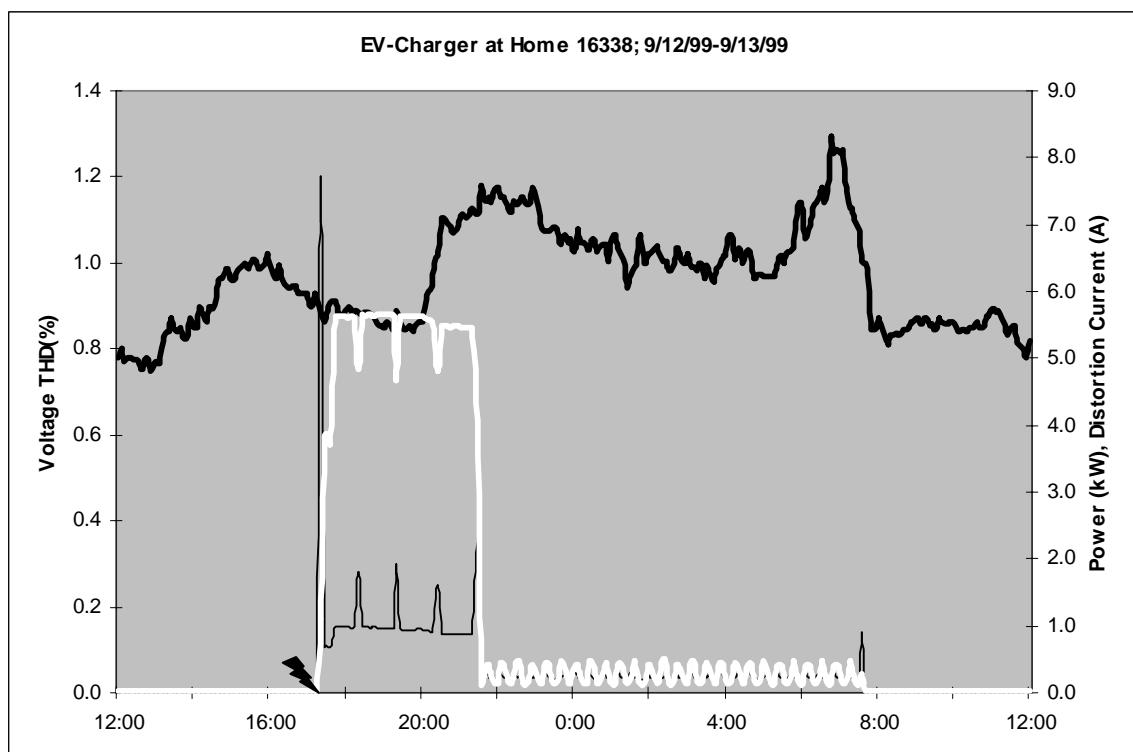
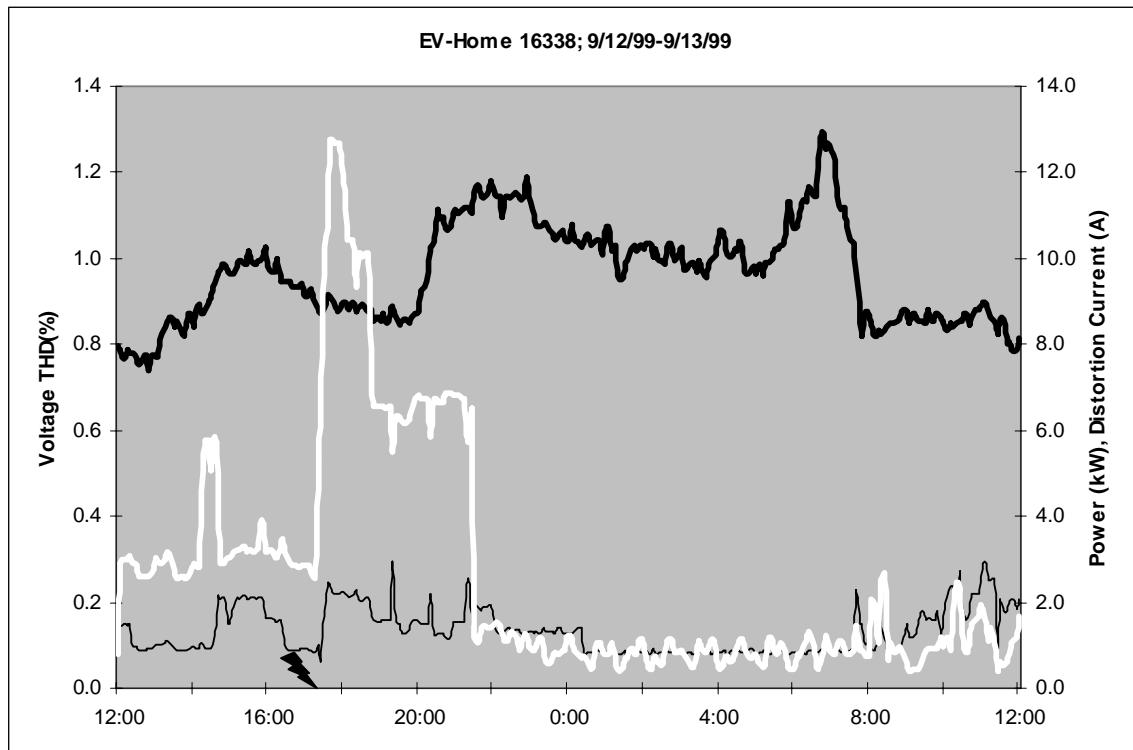


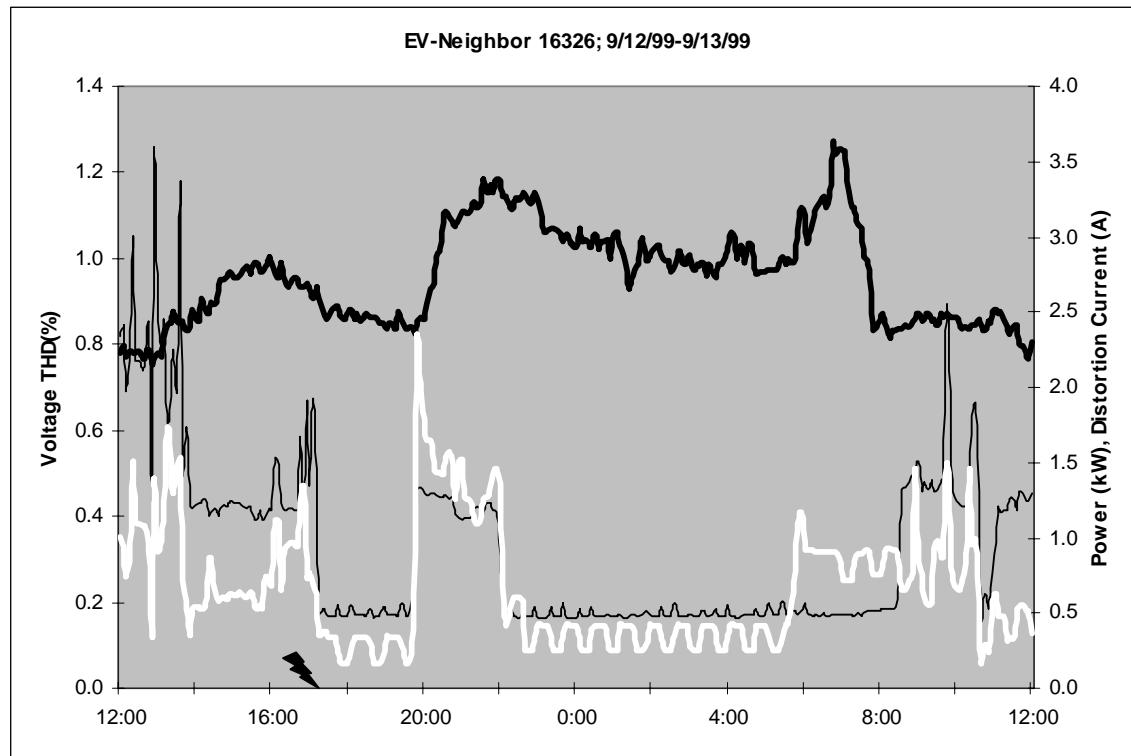




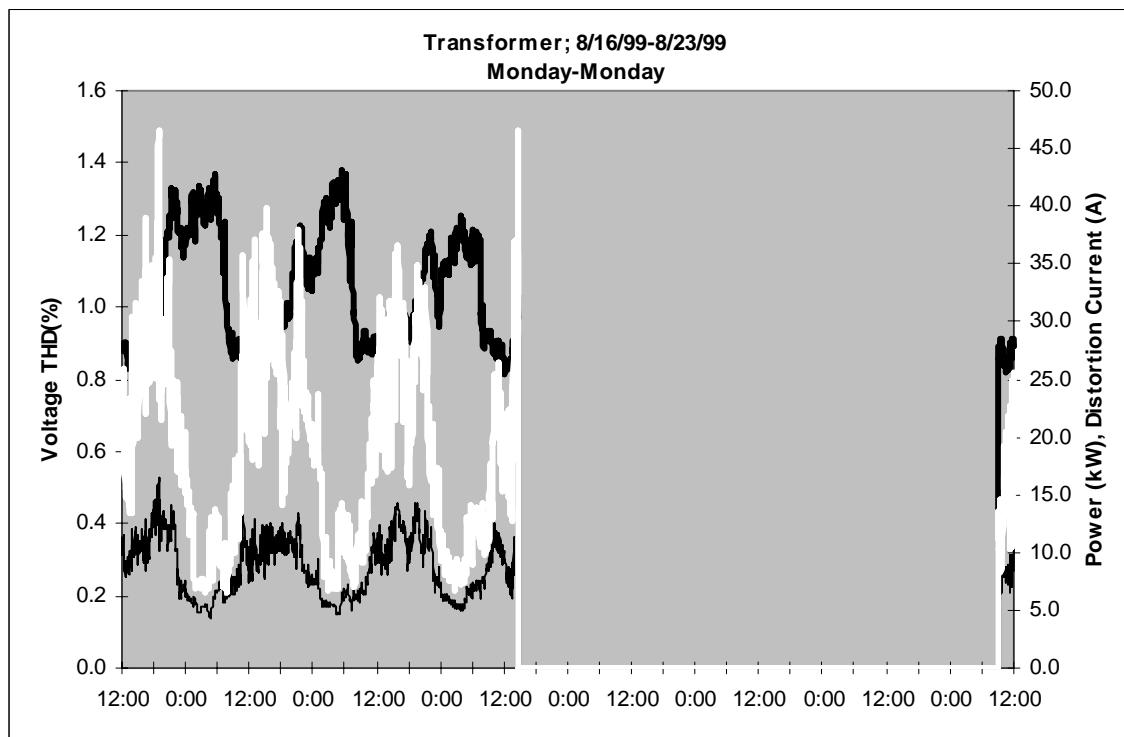
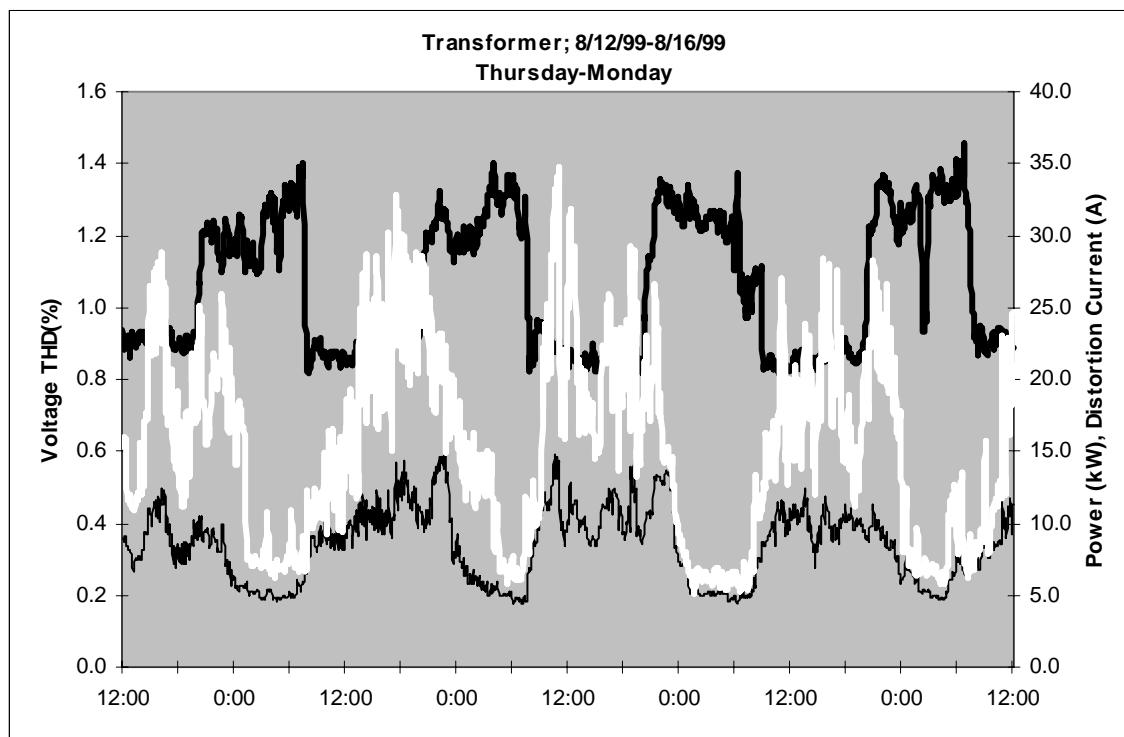


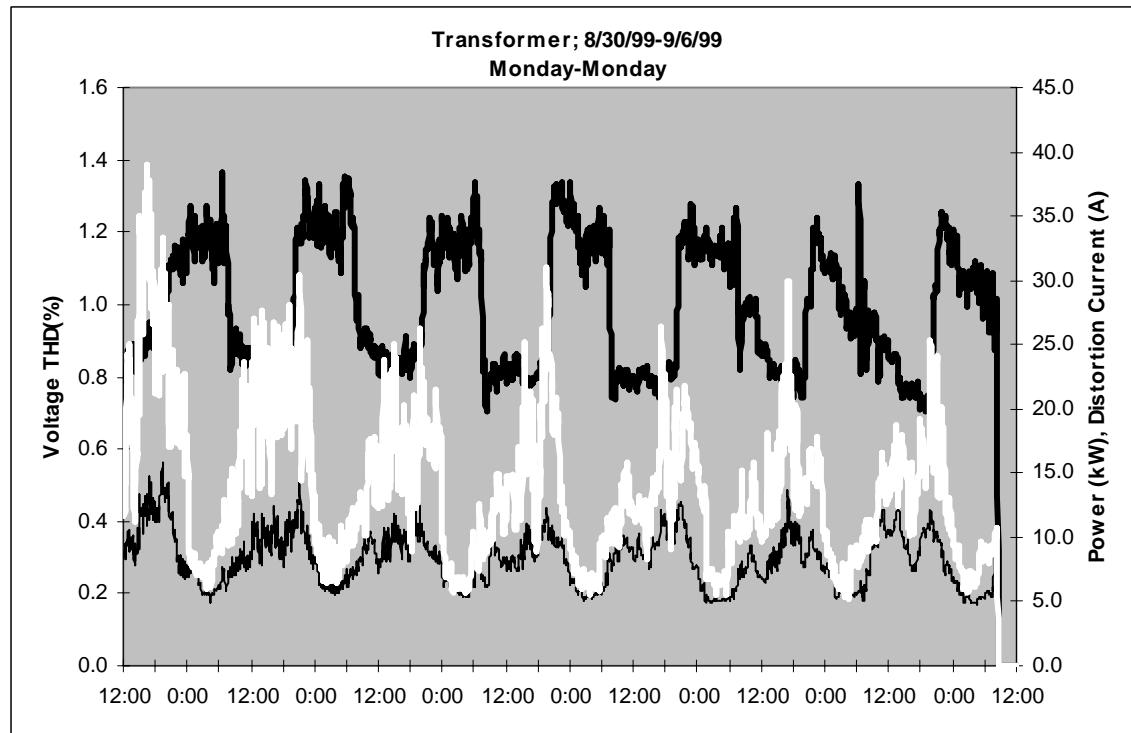
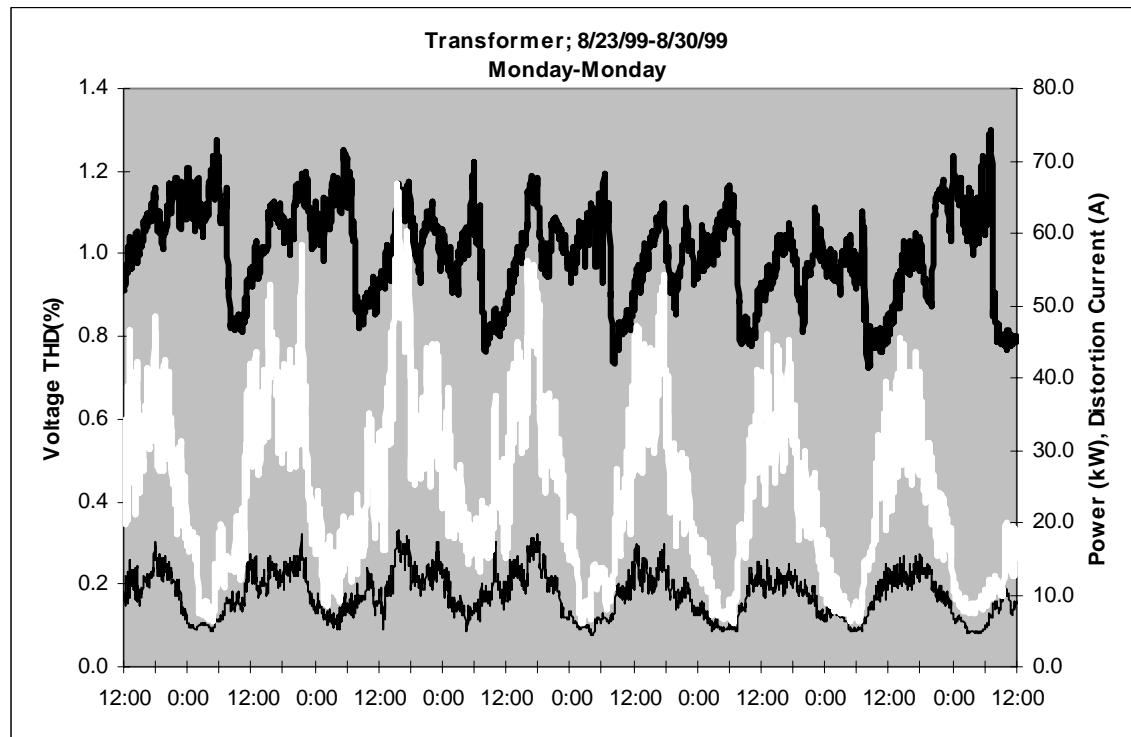


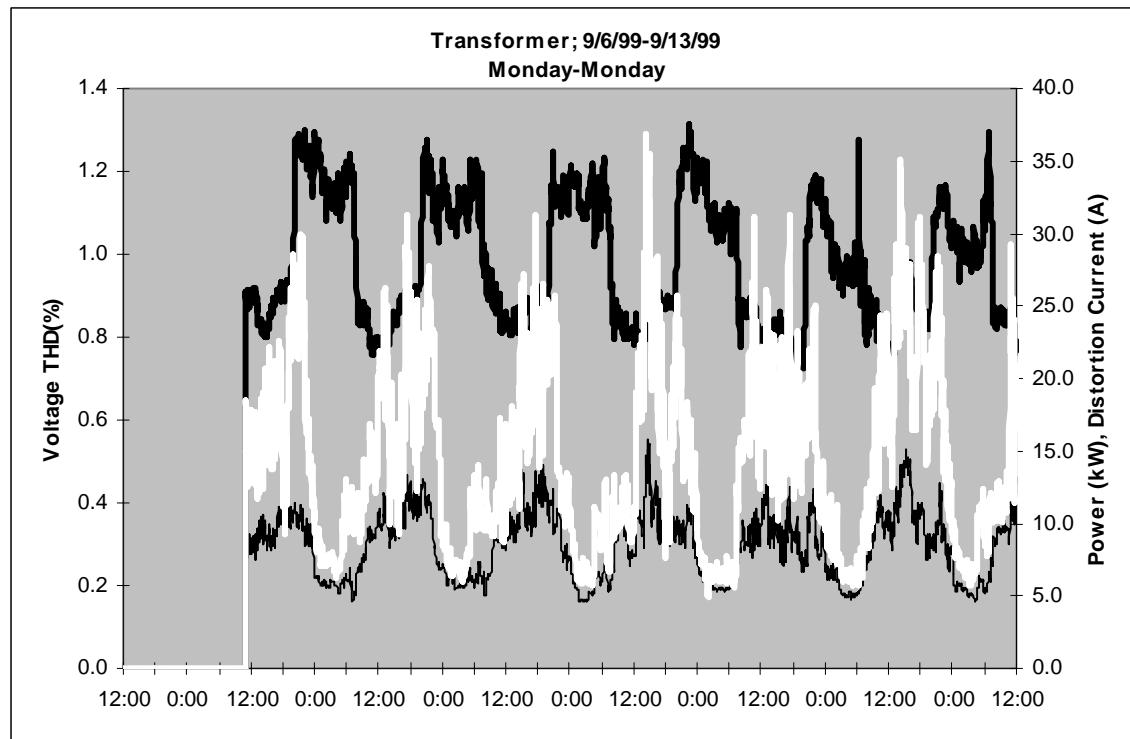




UTILITY E WEEKLY GRAPHS









Appendix D.3

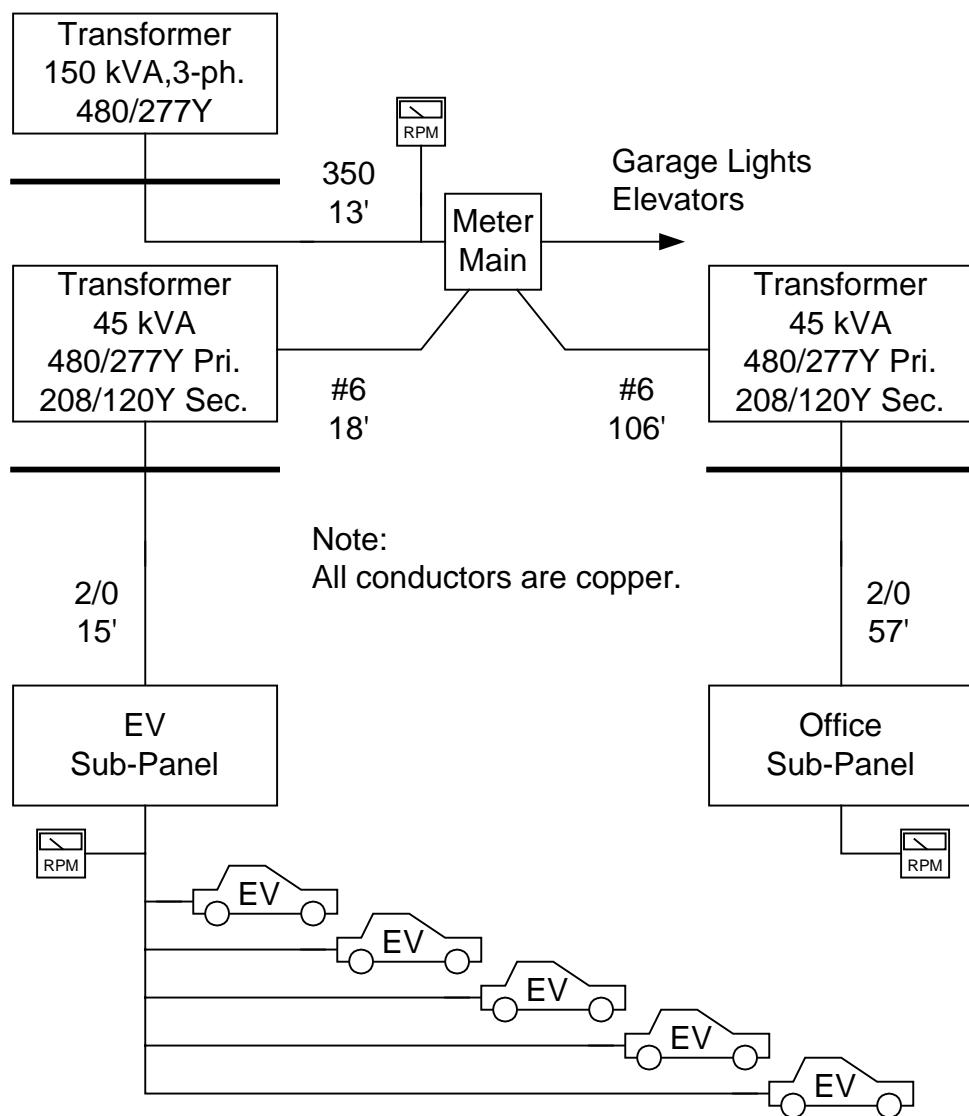
Utility C Data



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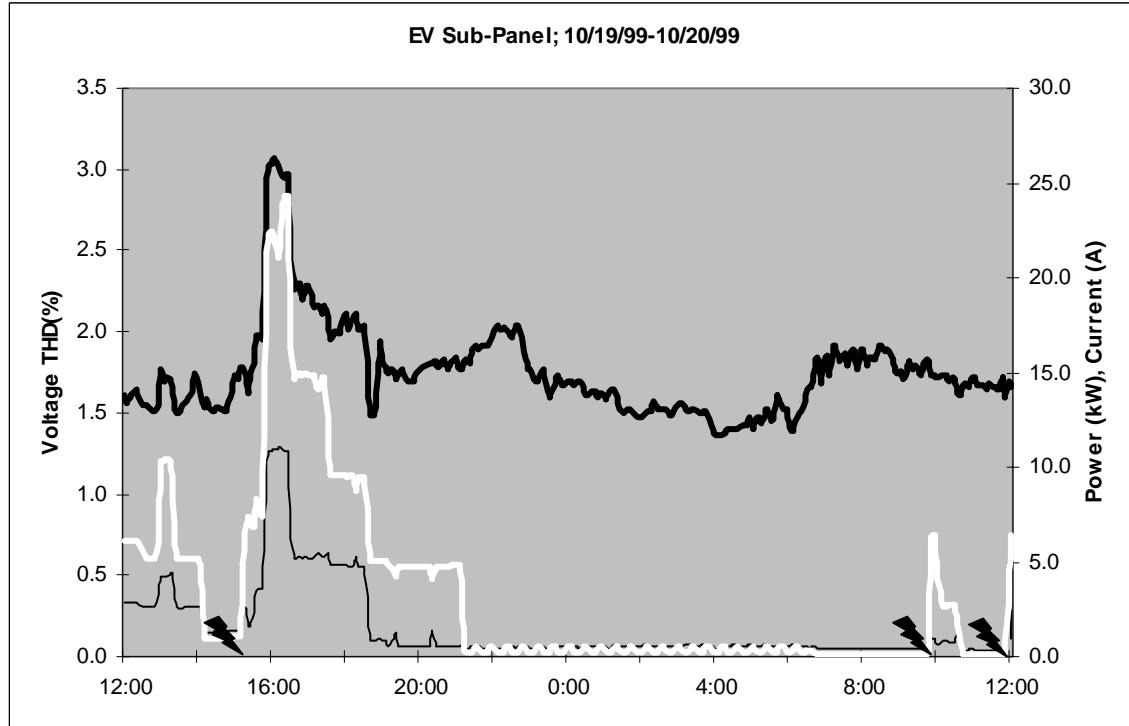
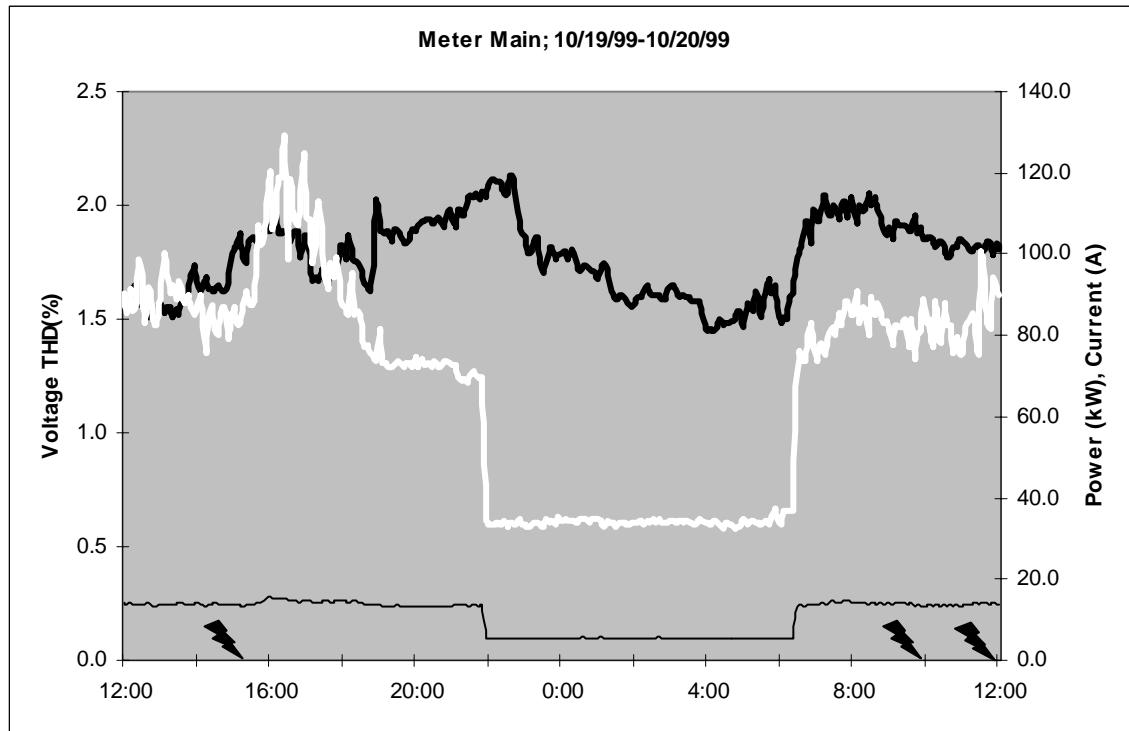
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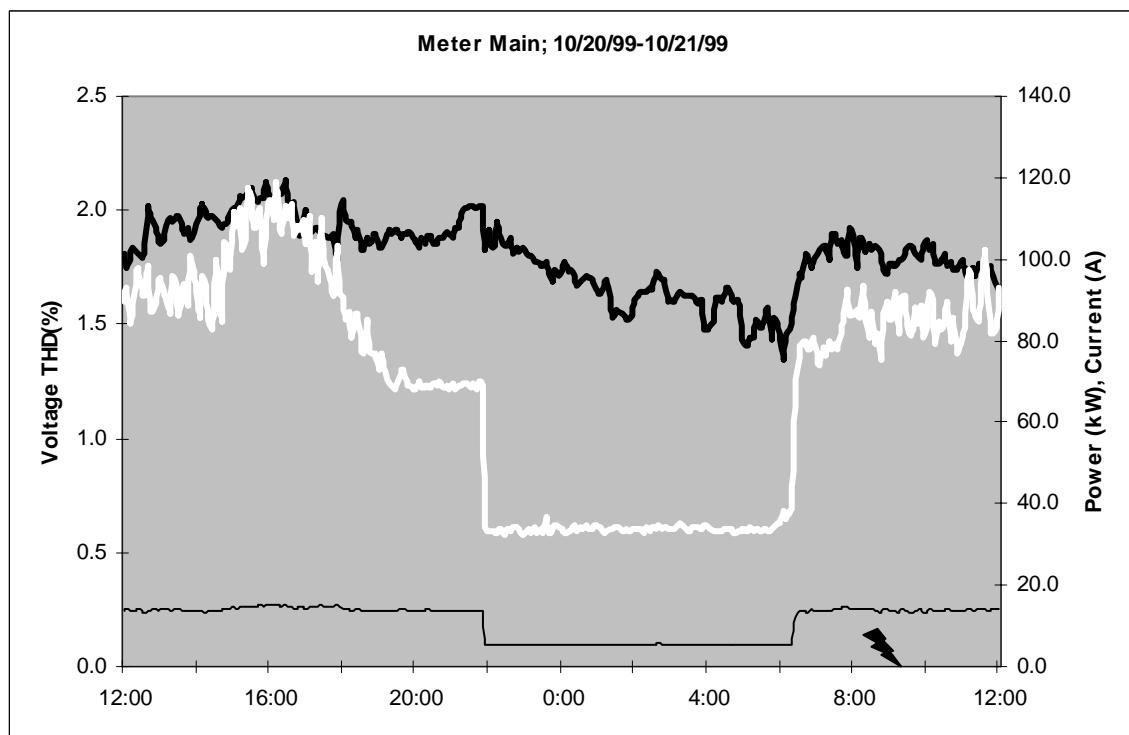
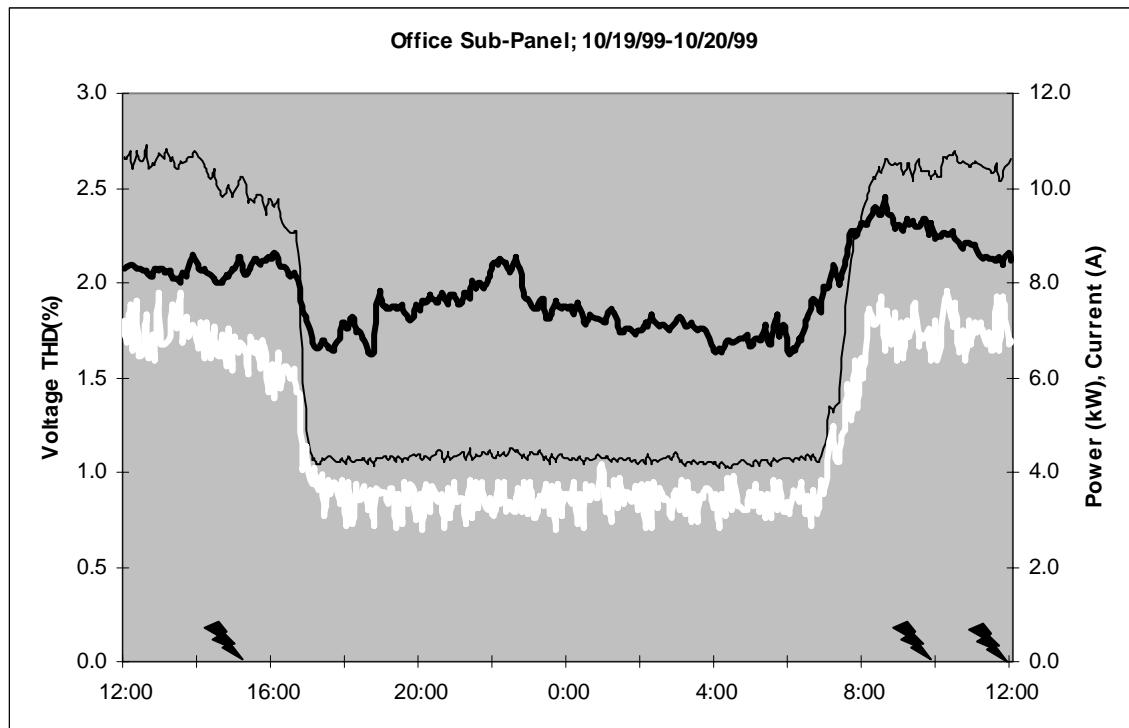


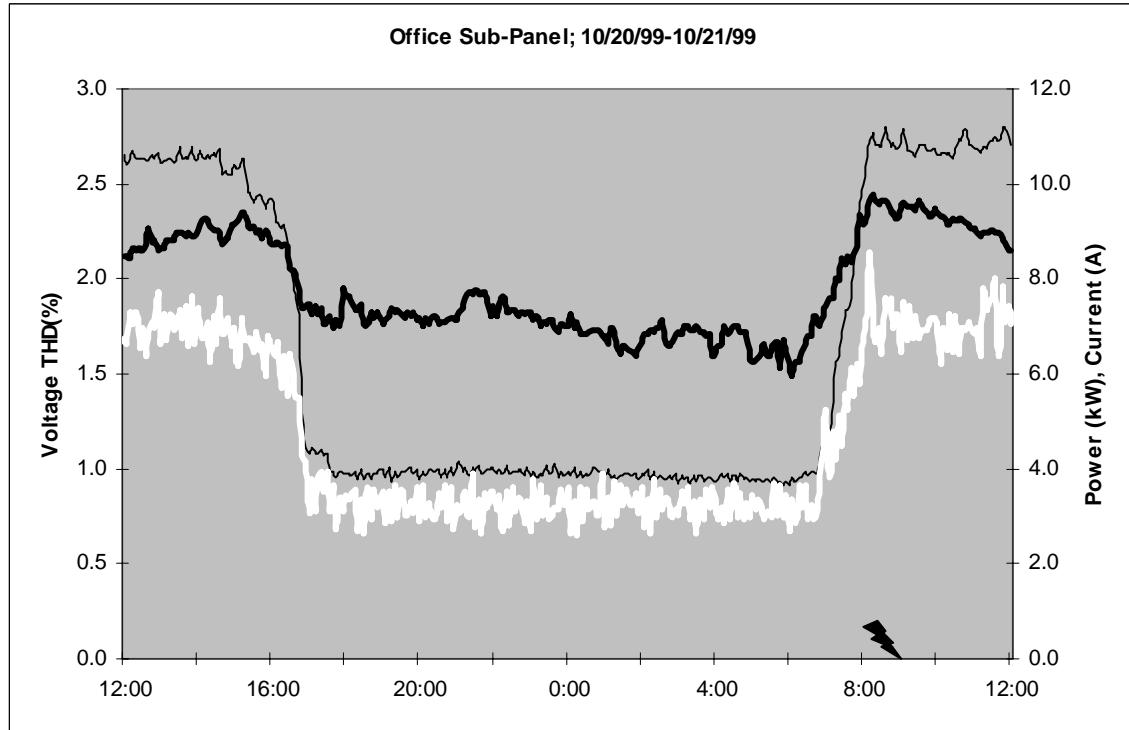
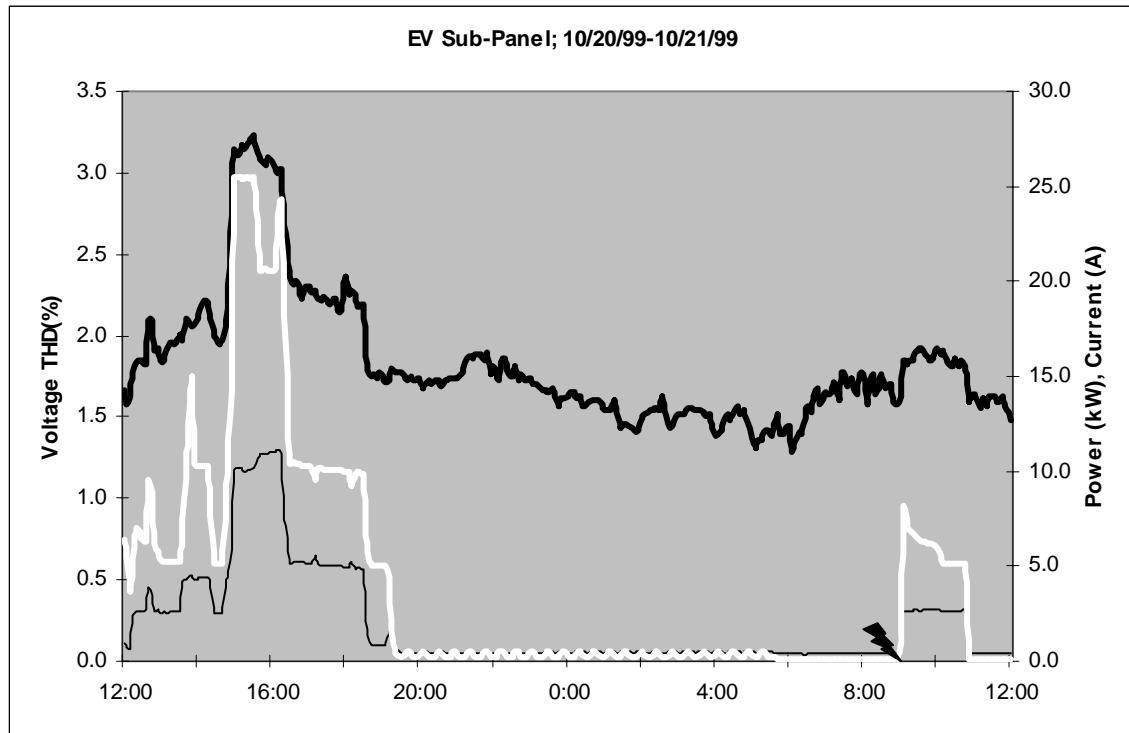
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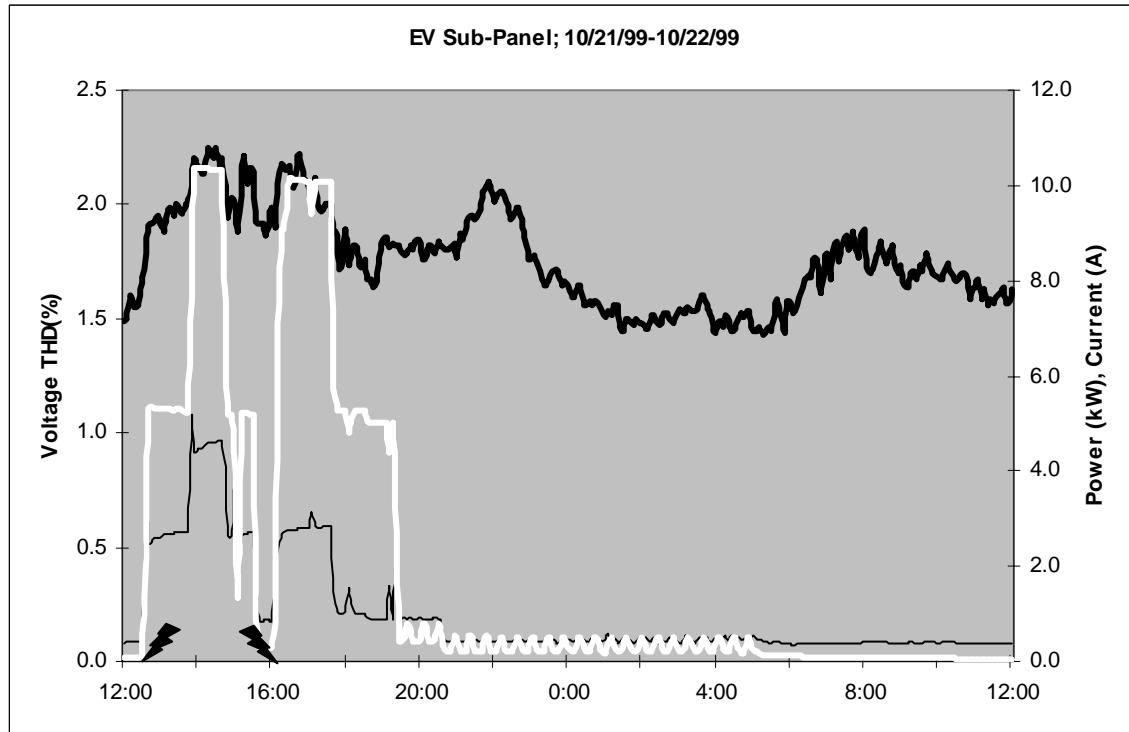
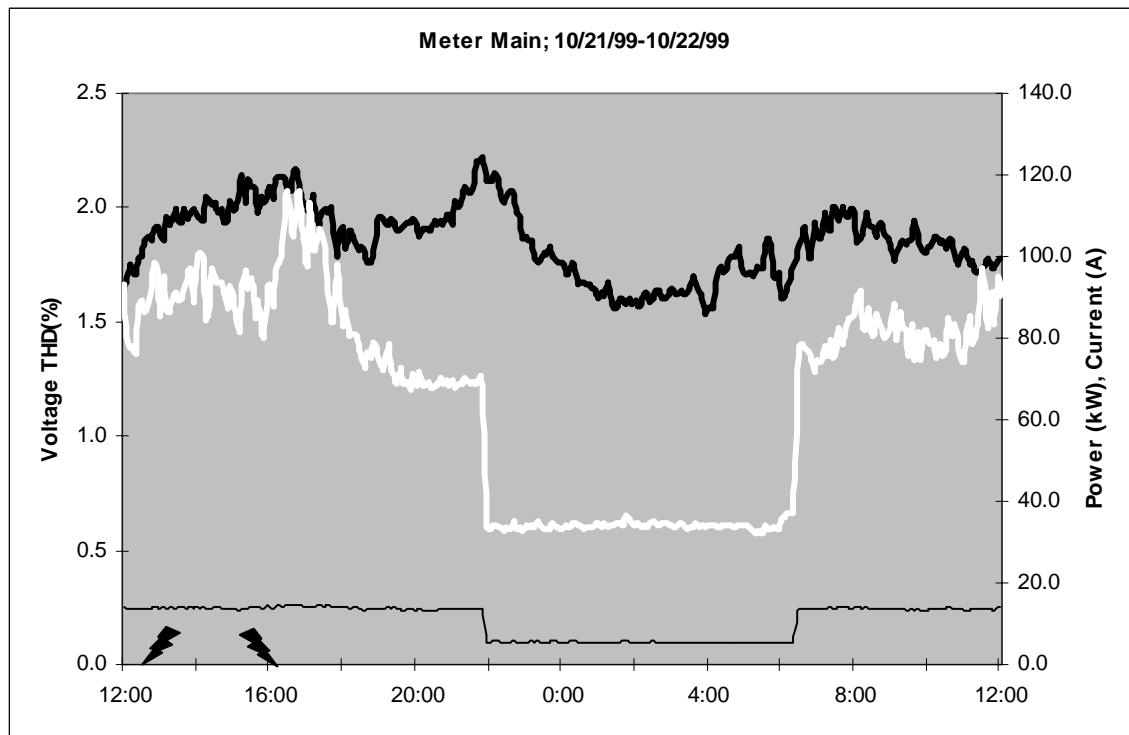


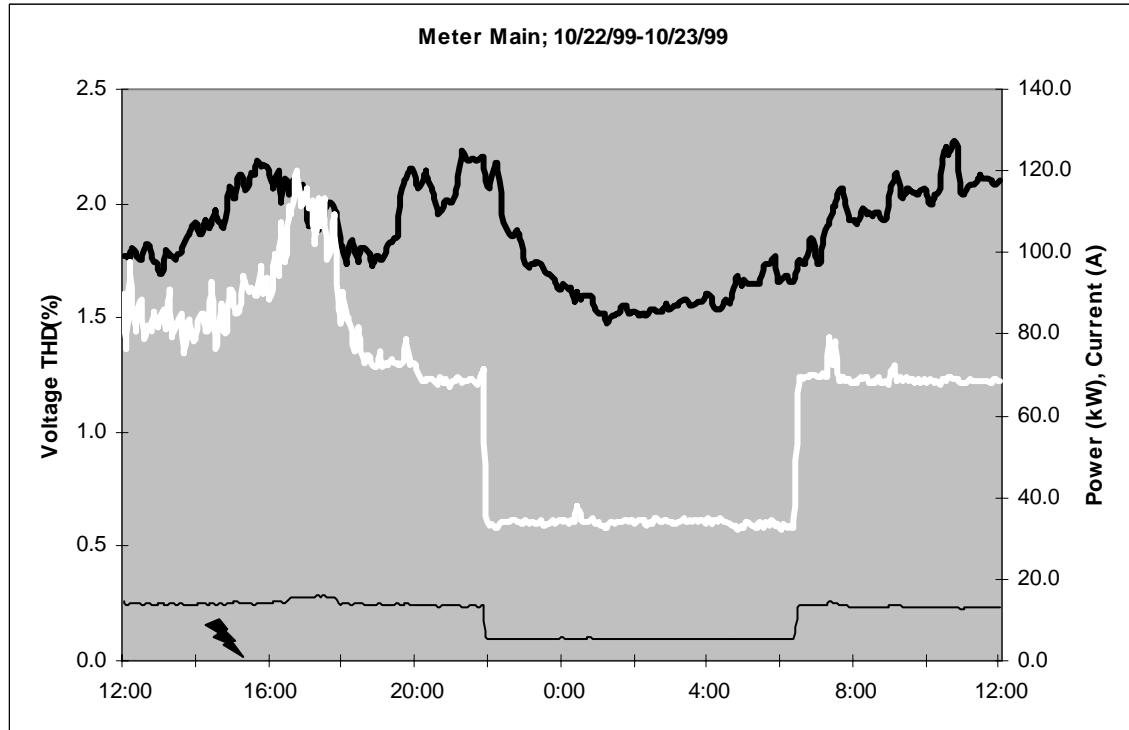
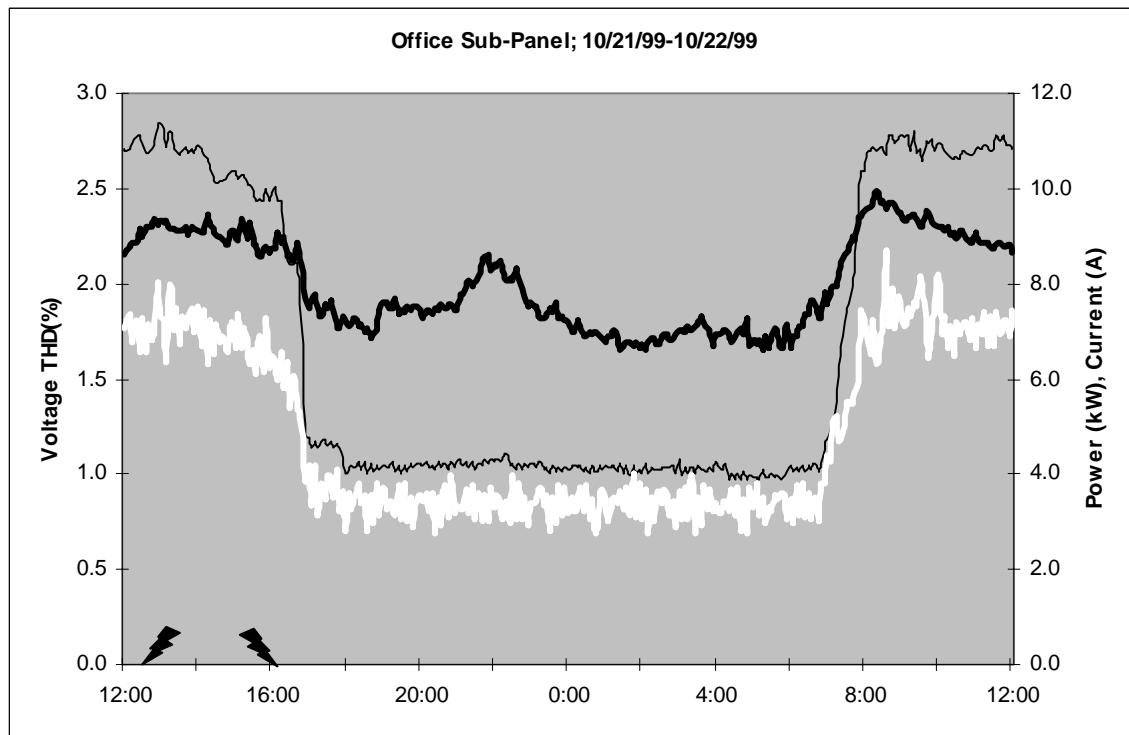
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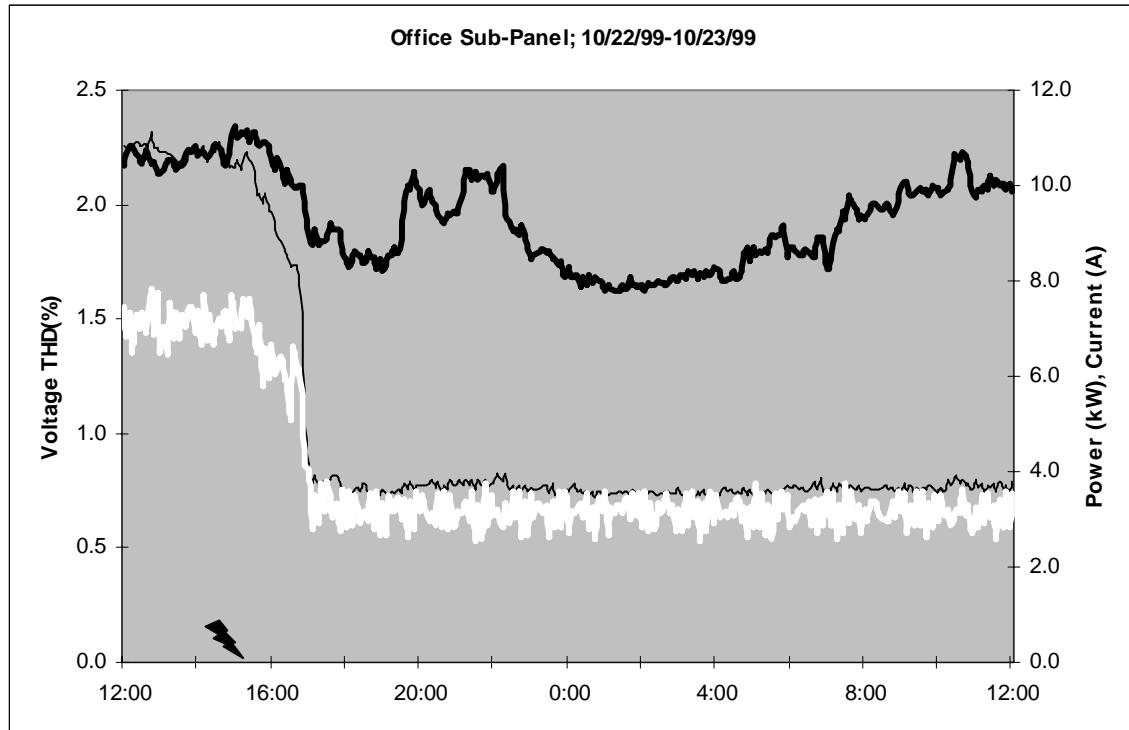
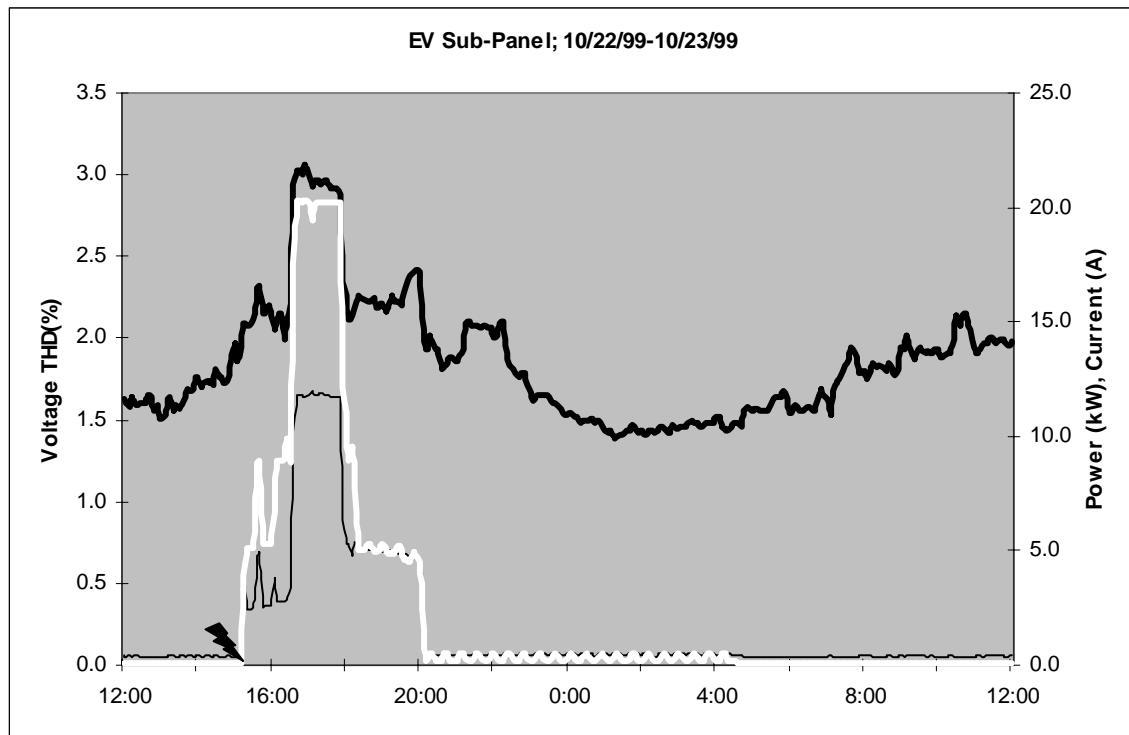


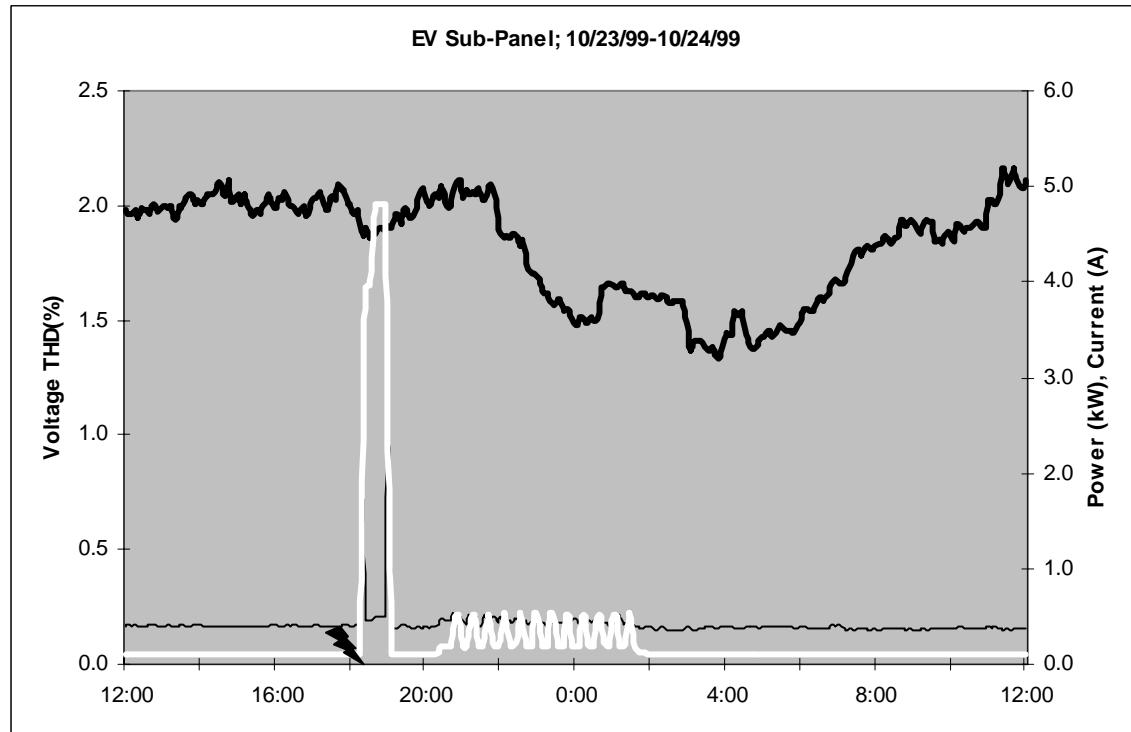
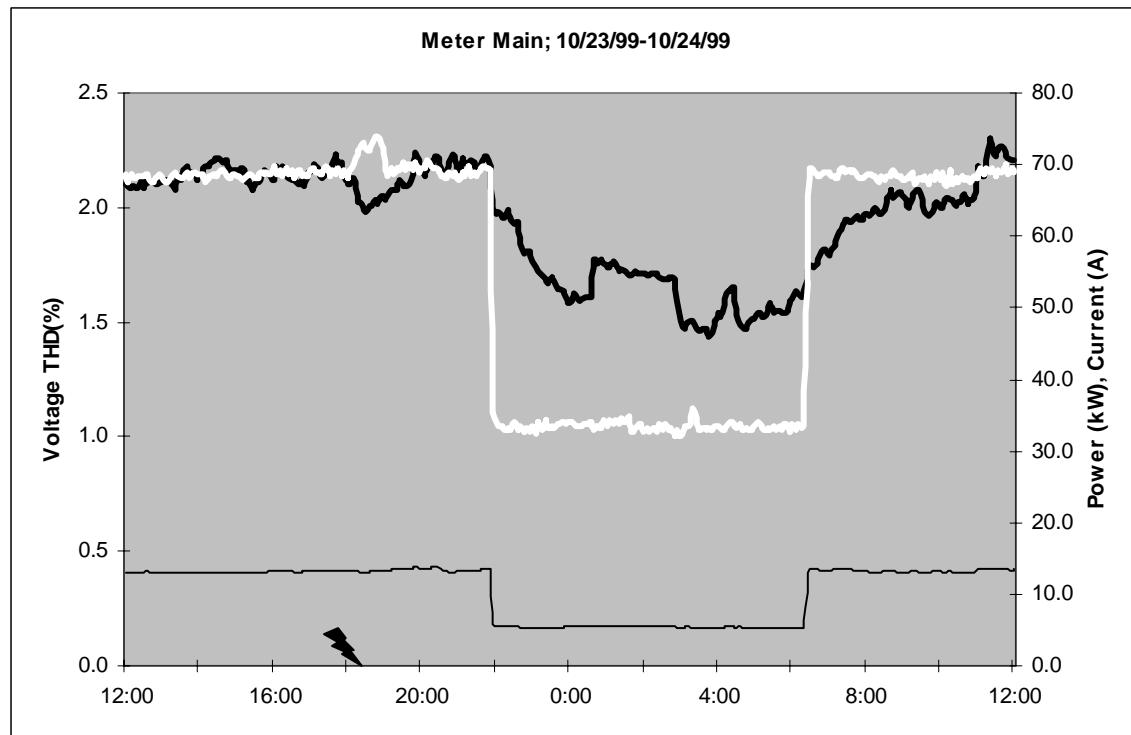


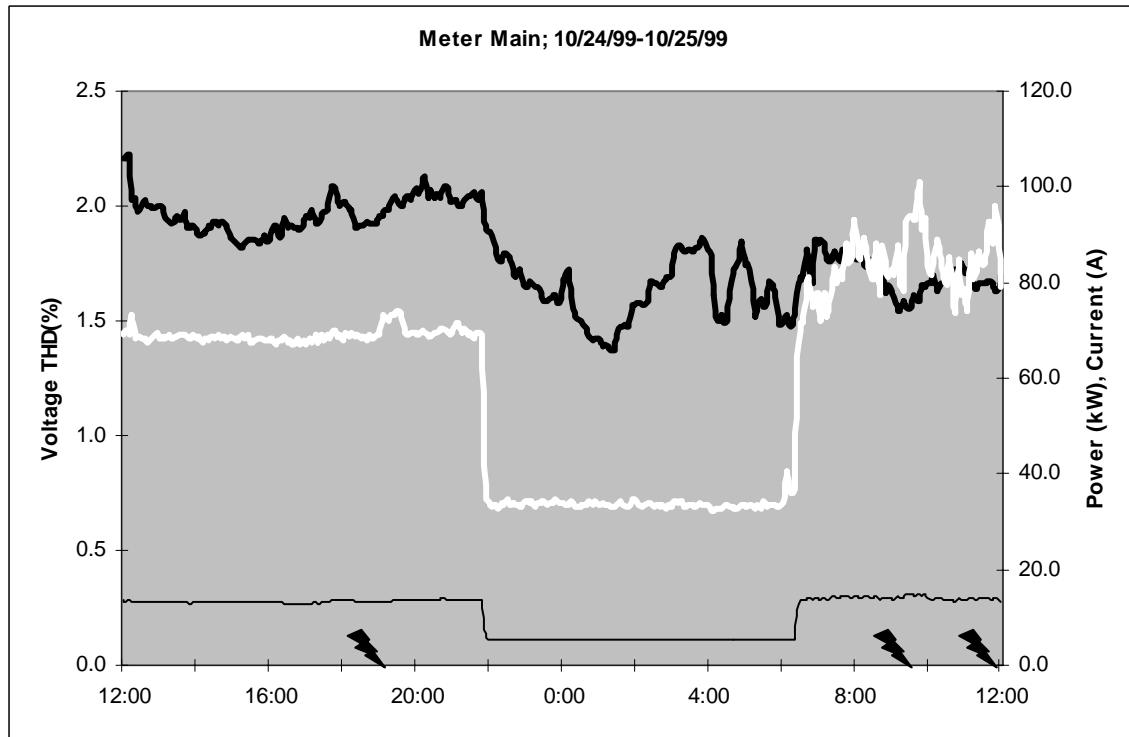
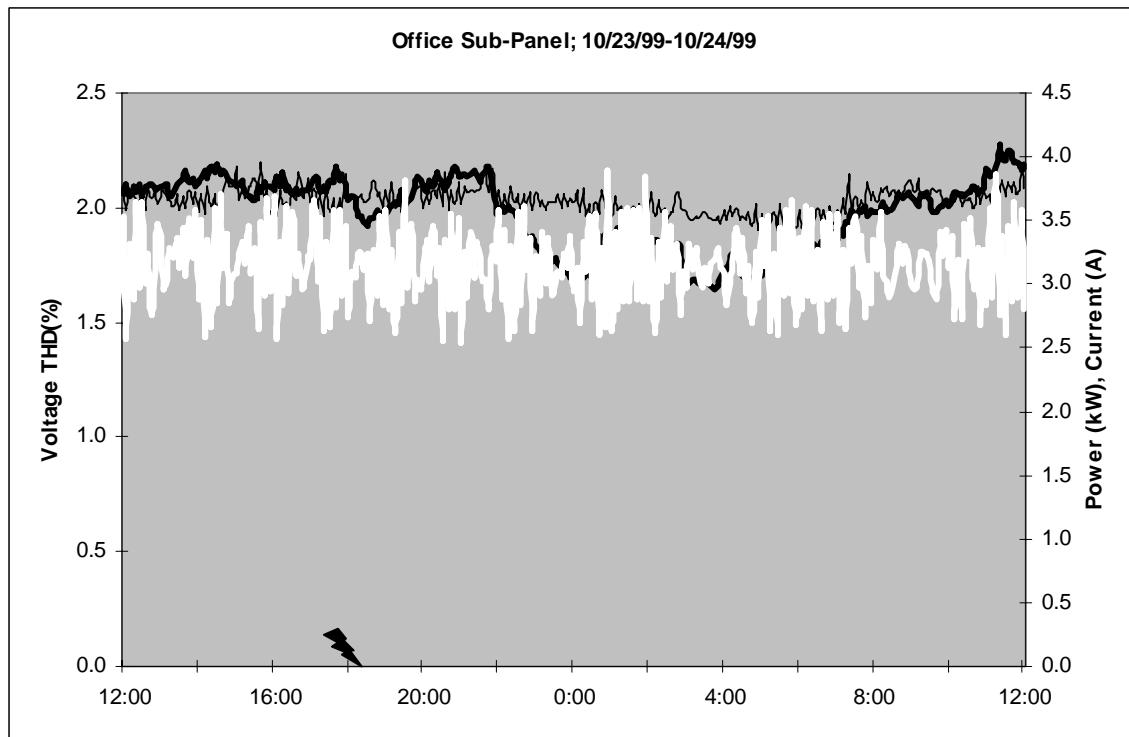


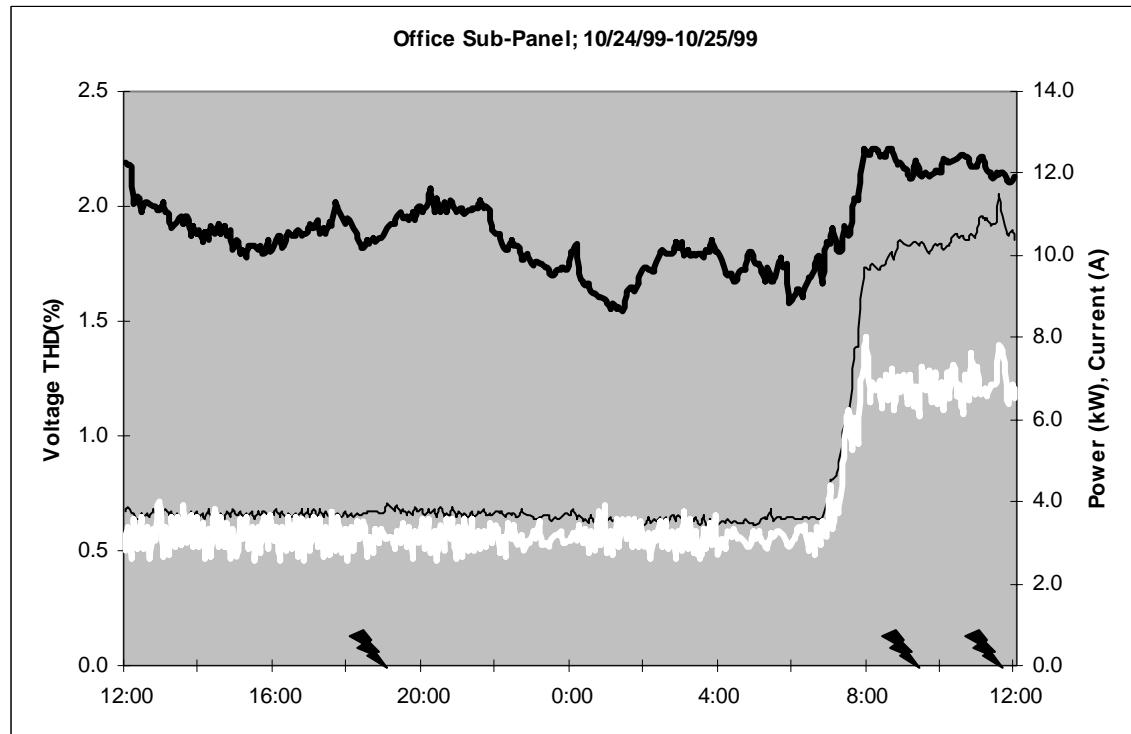
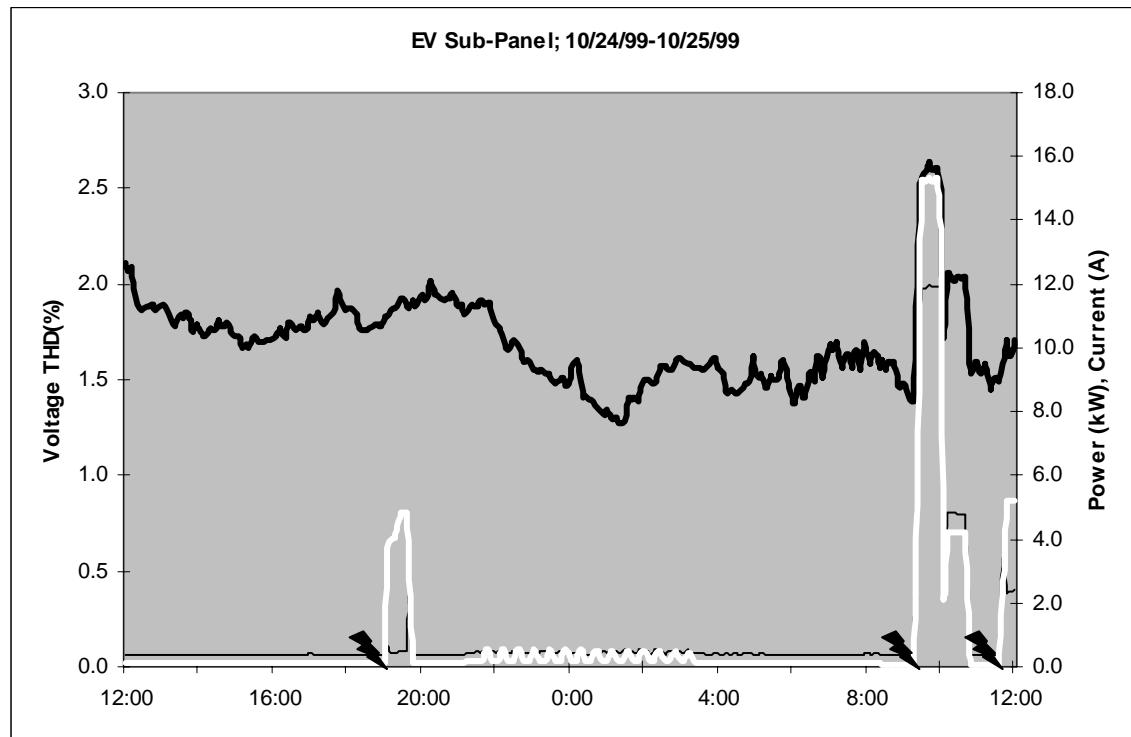


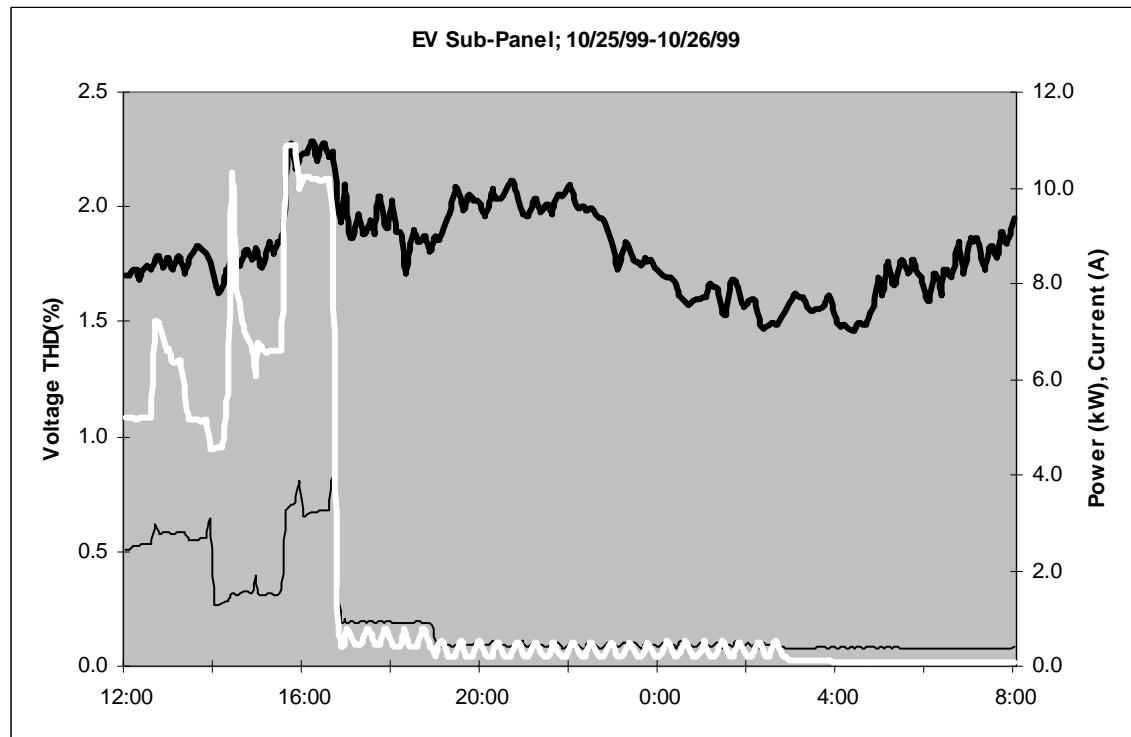
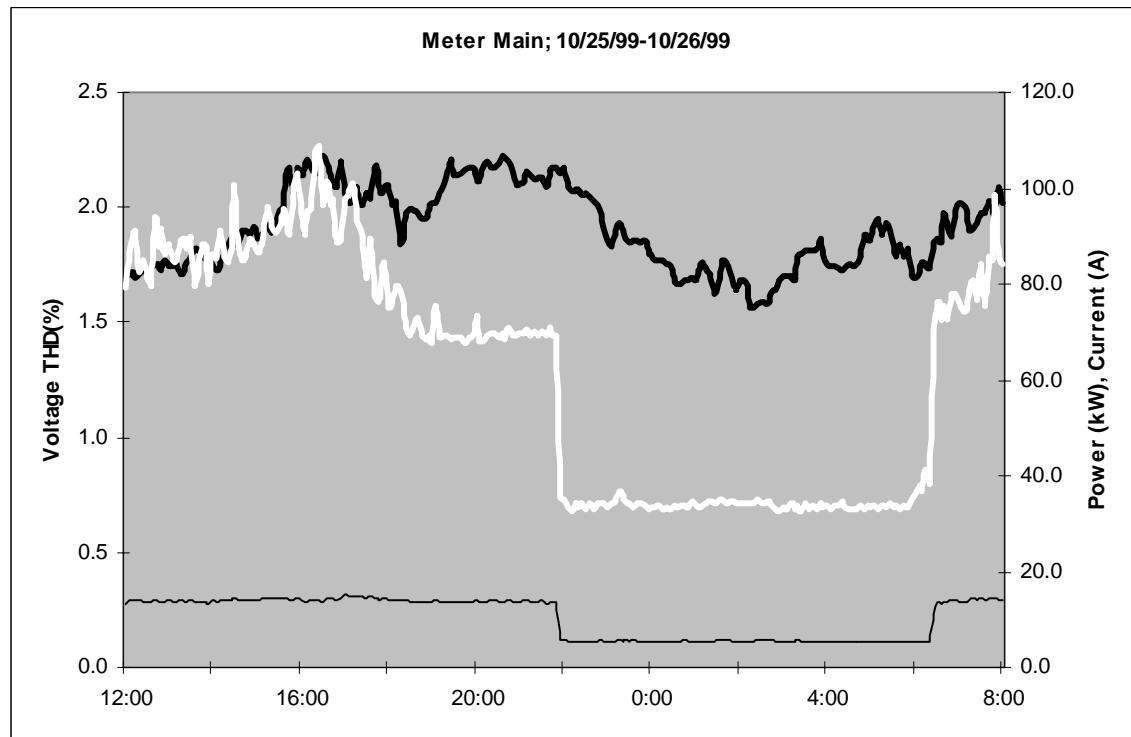


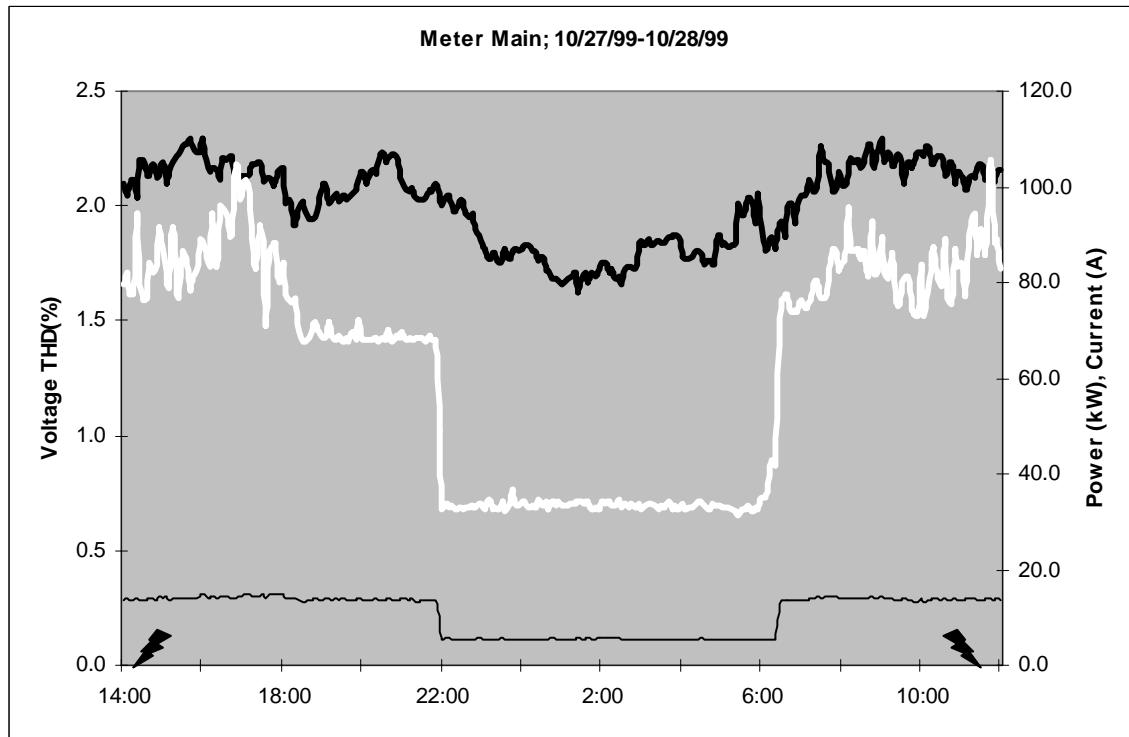
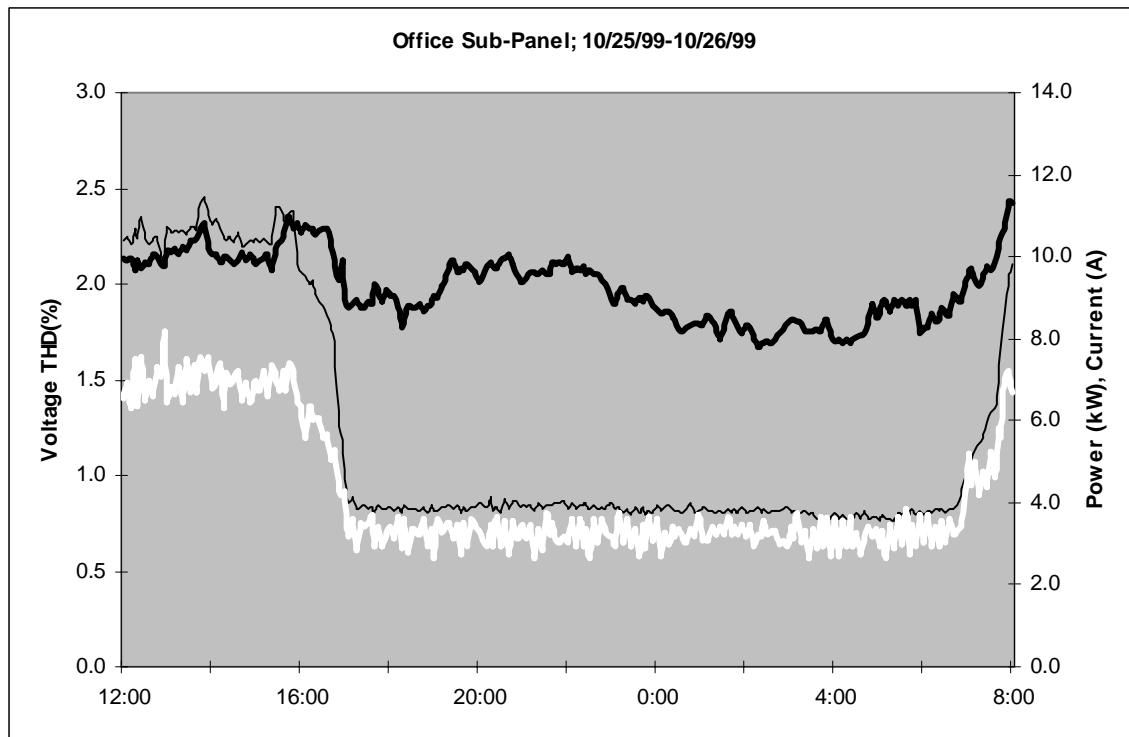


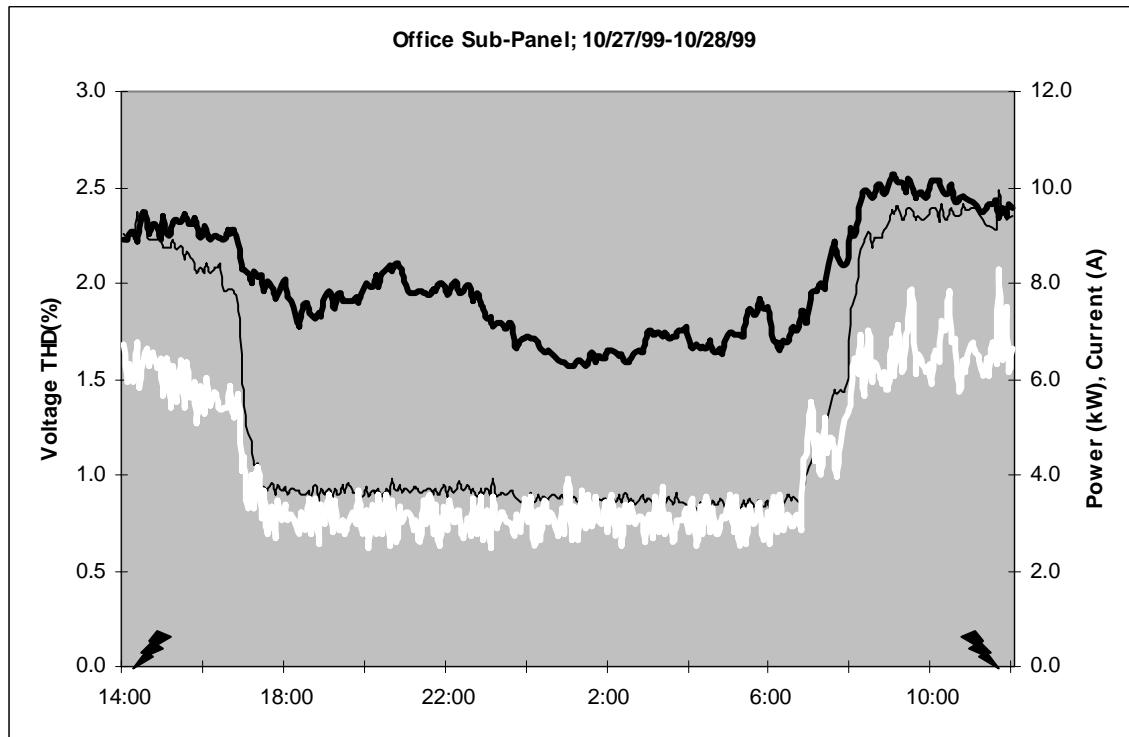
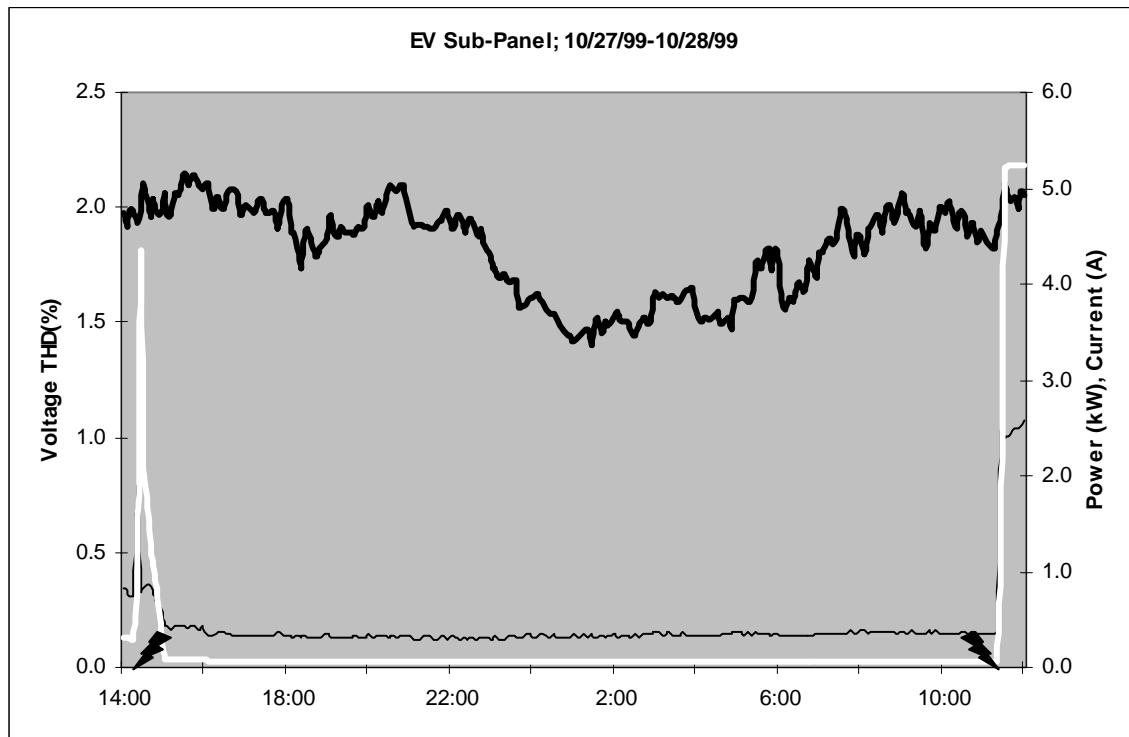


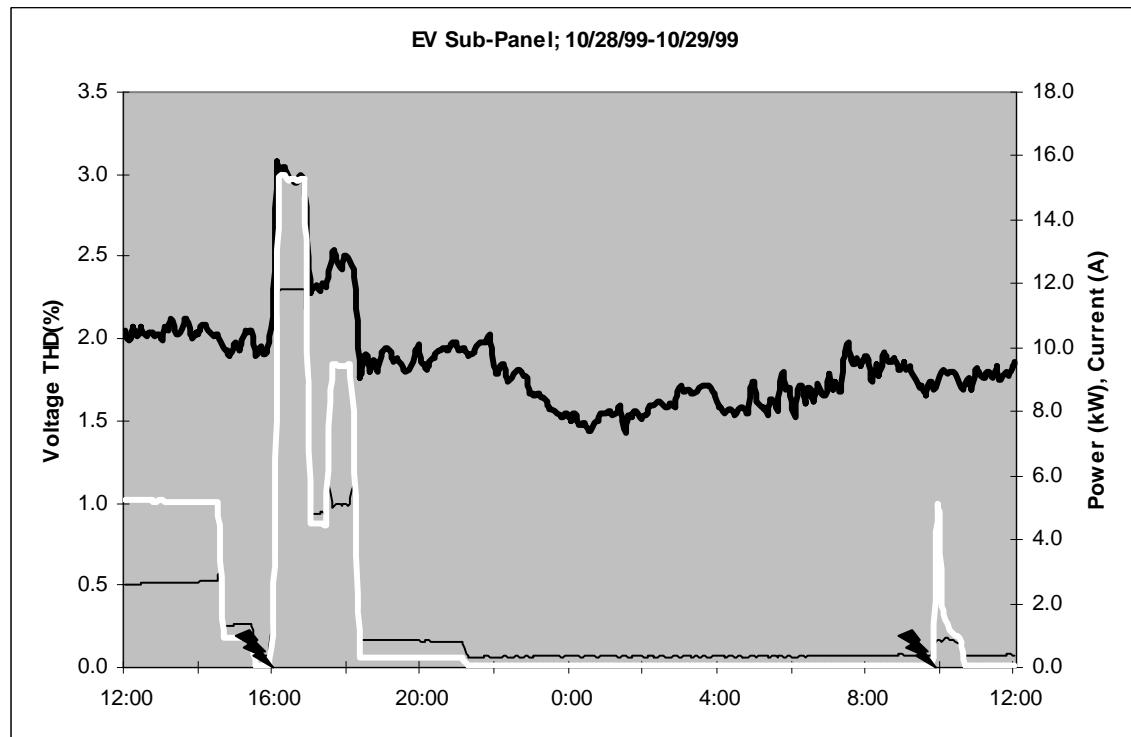
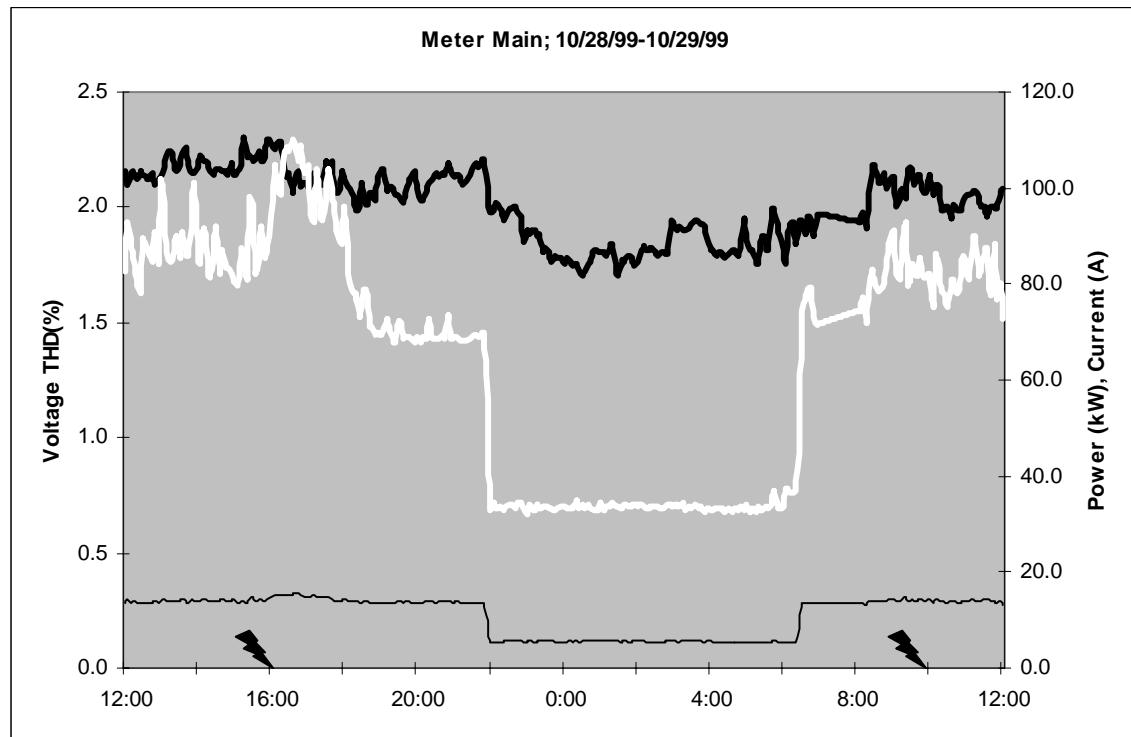


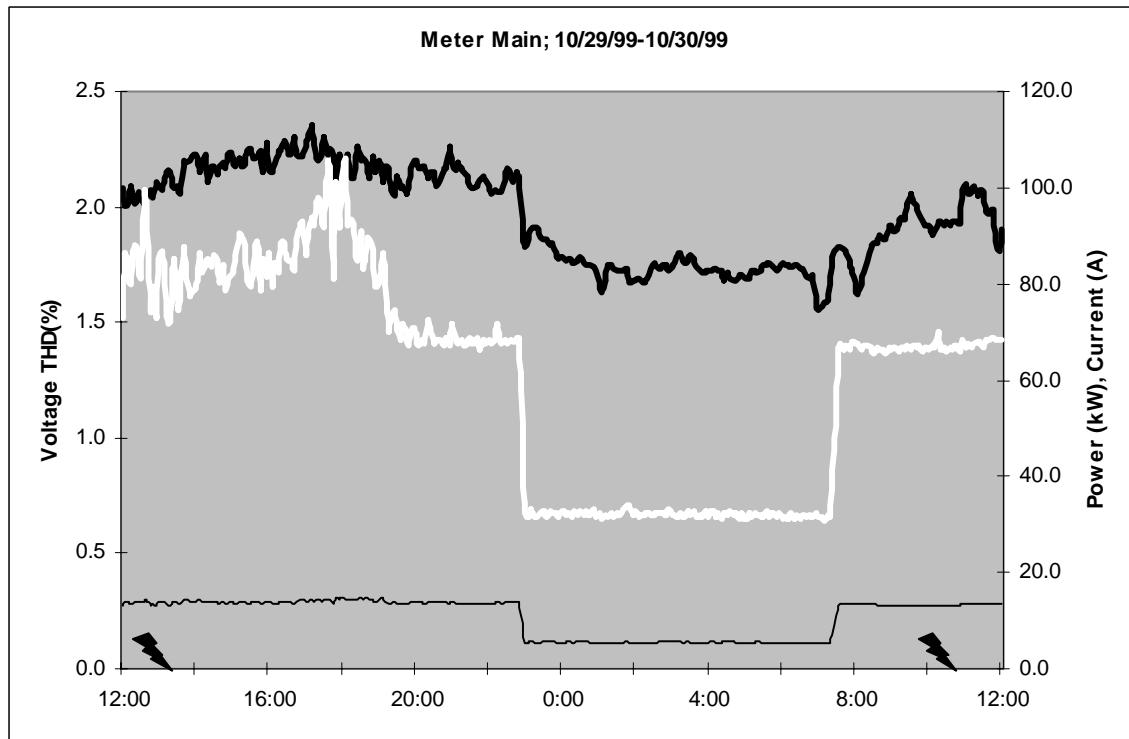
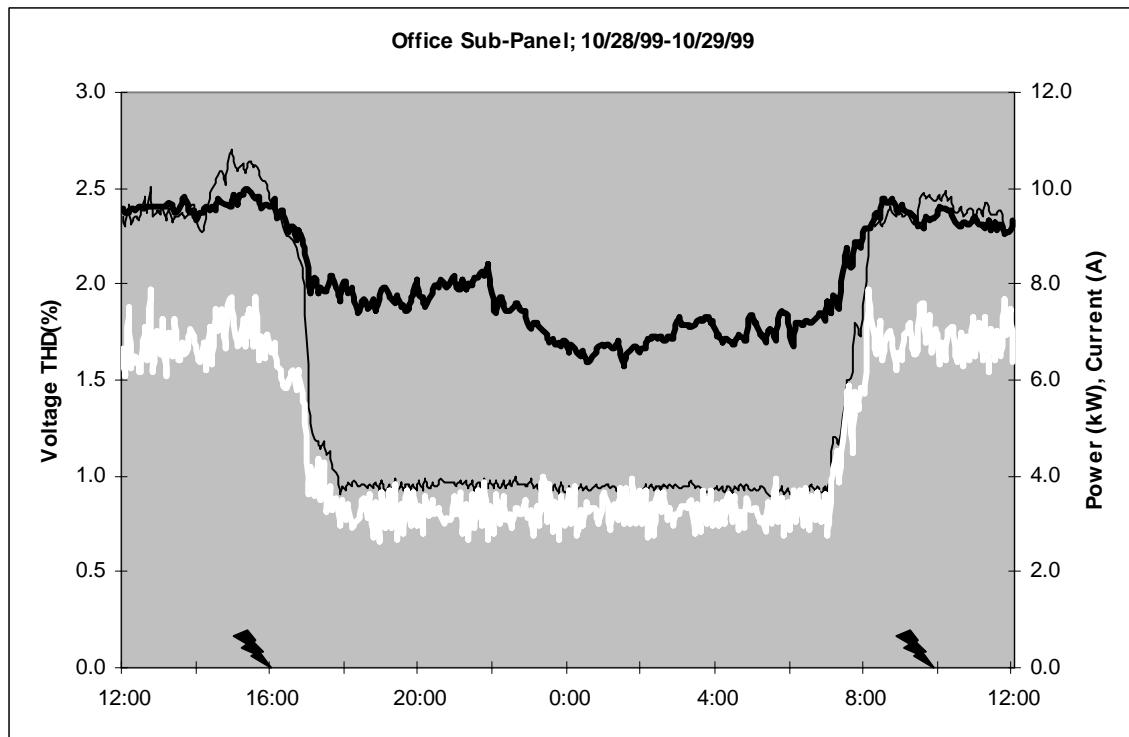


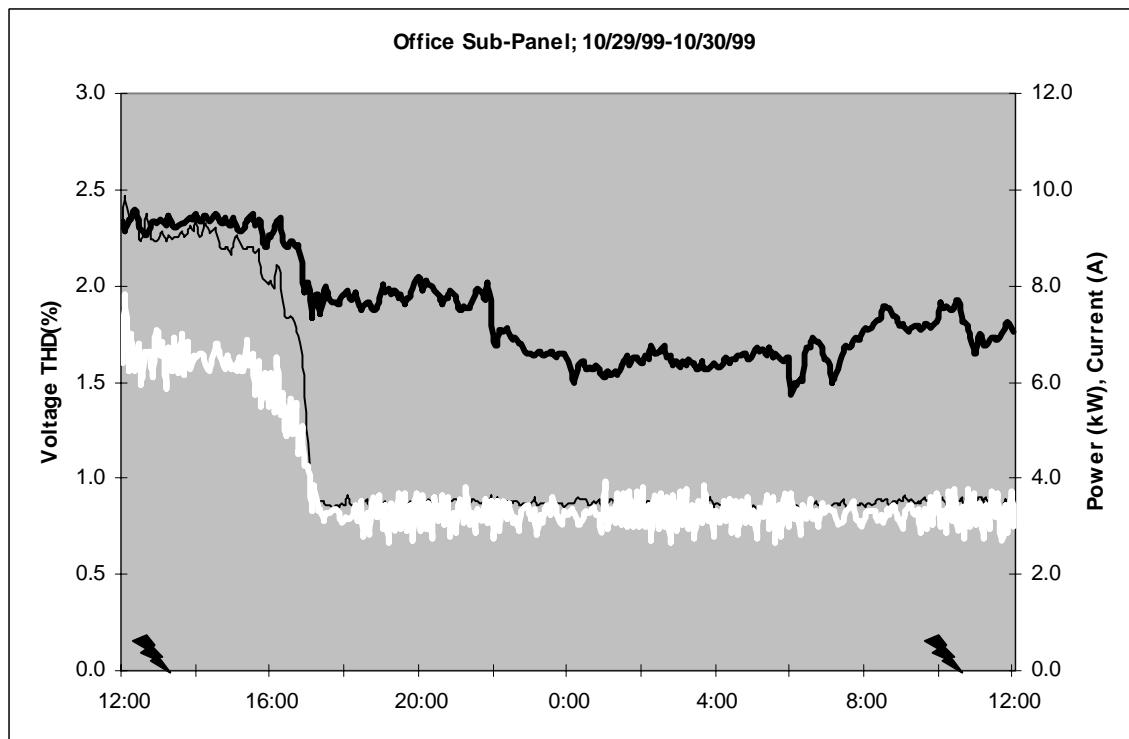
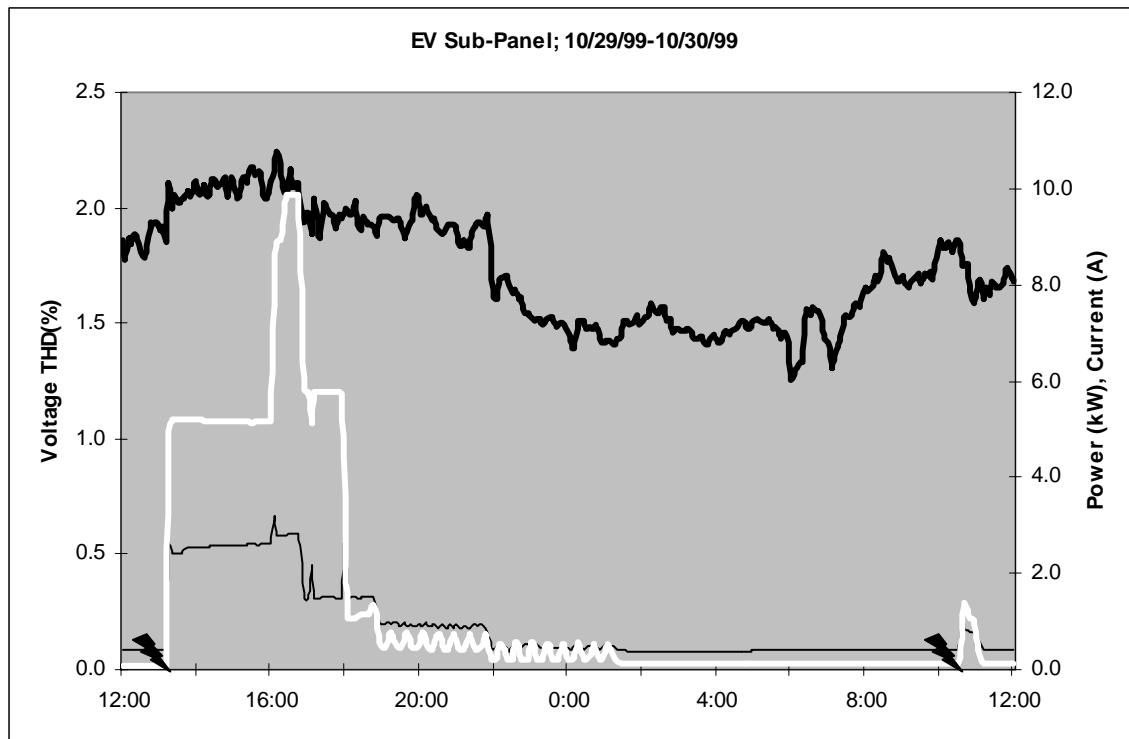


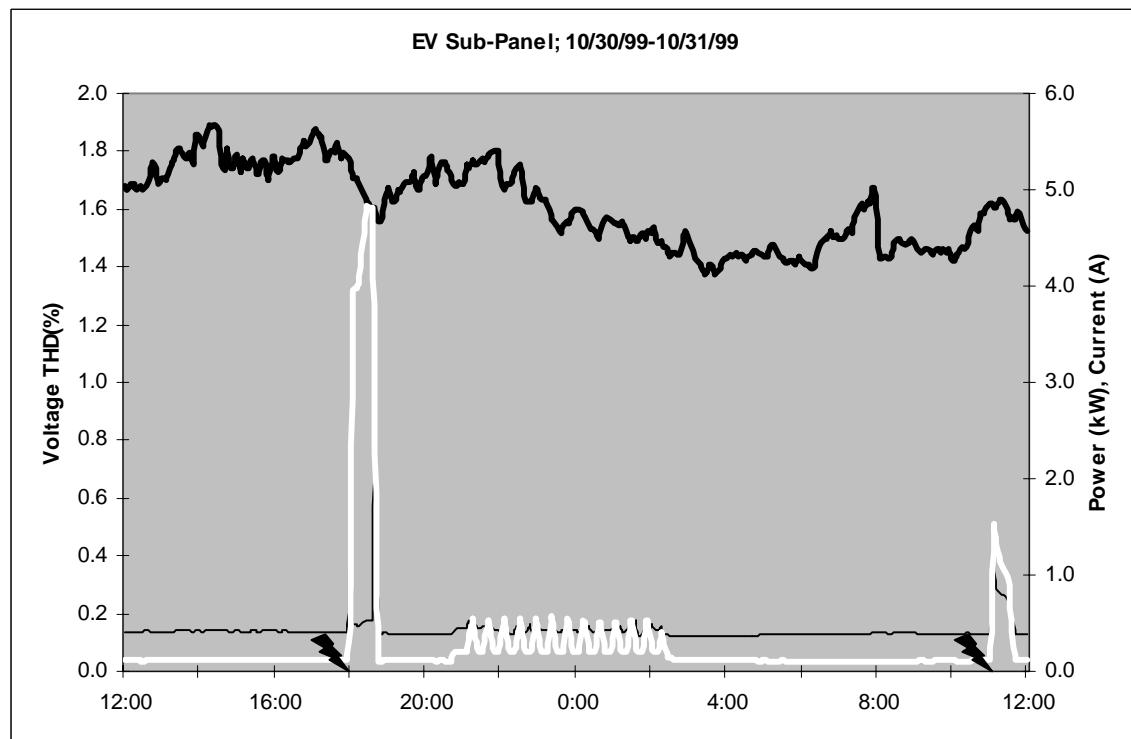
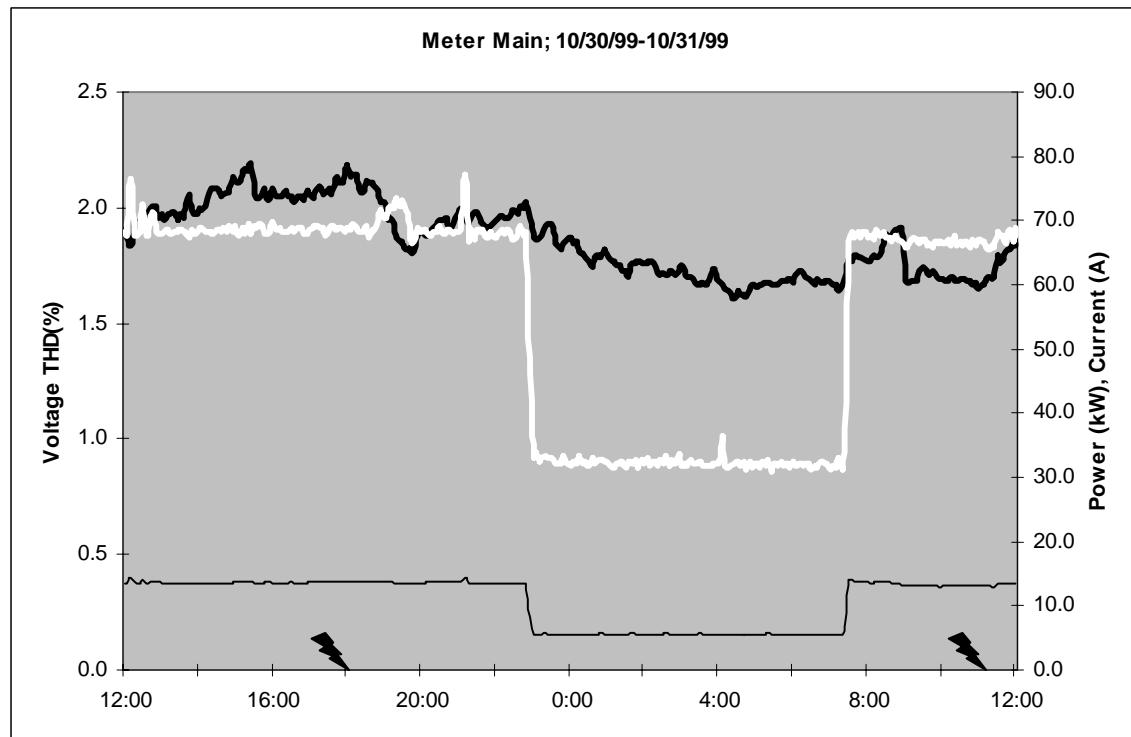


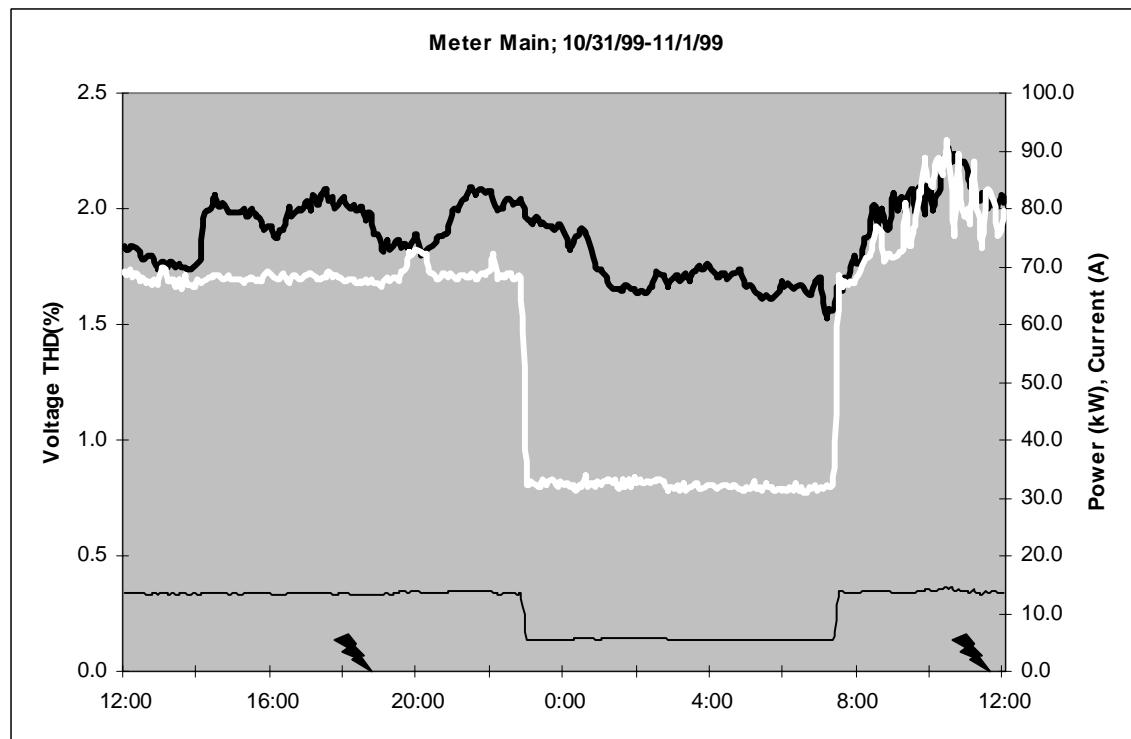
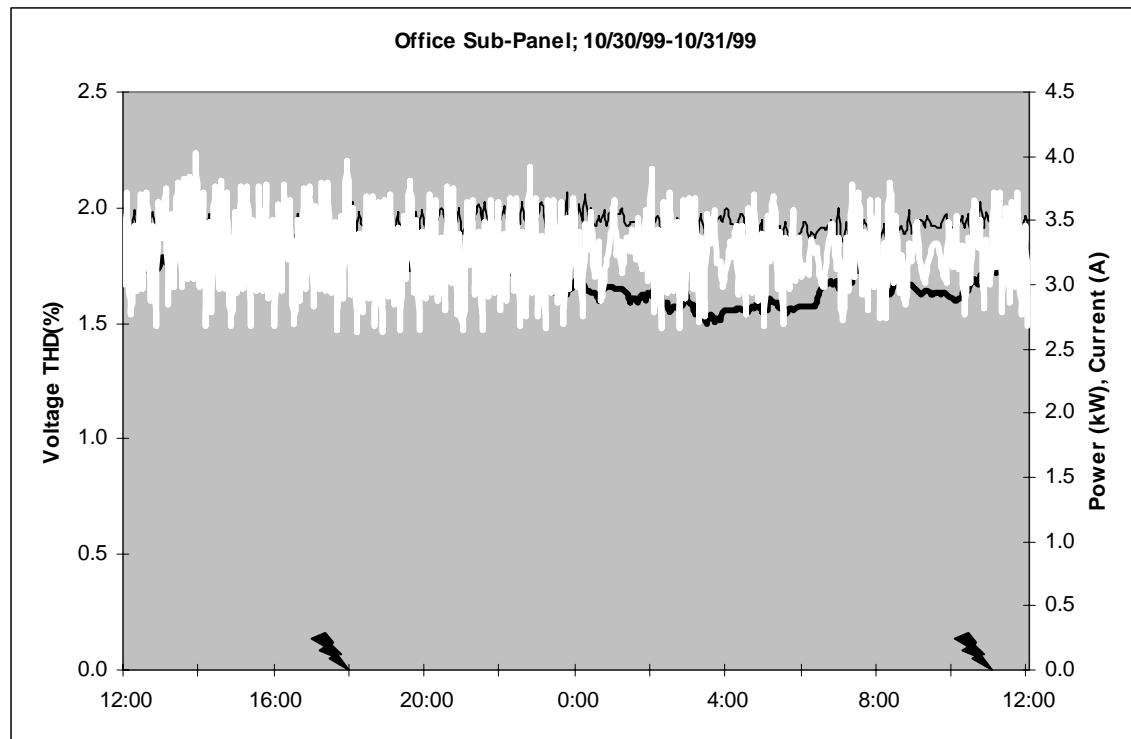


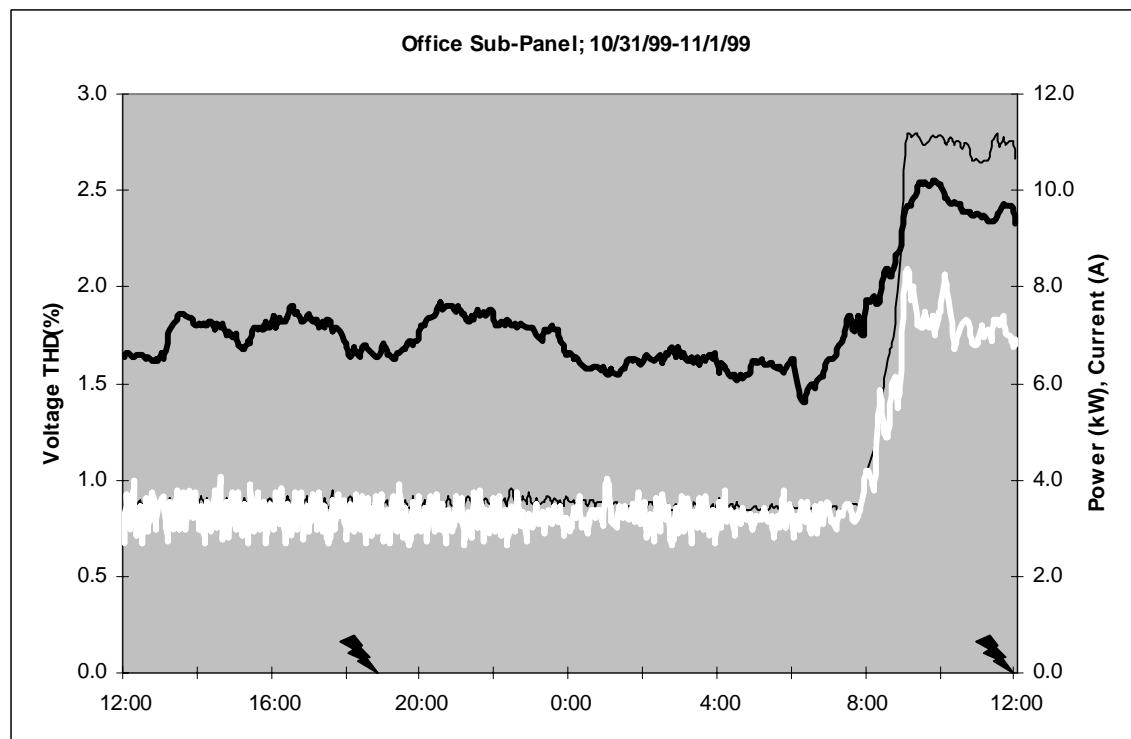
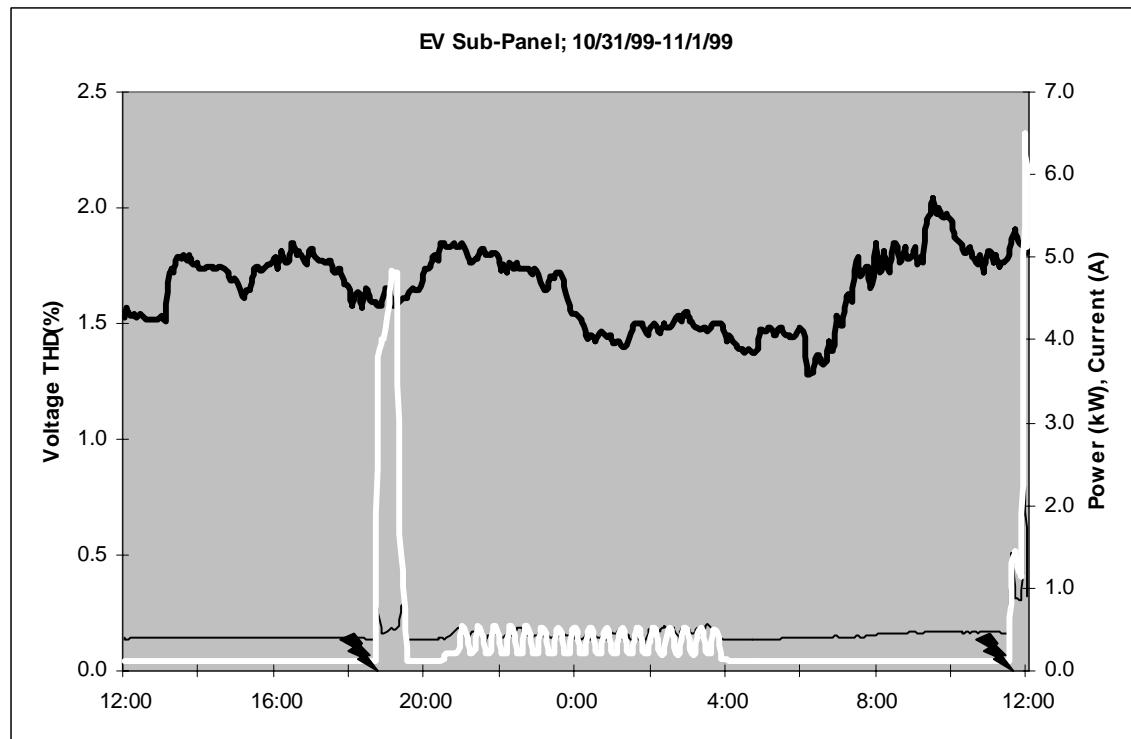


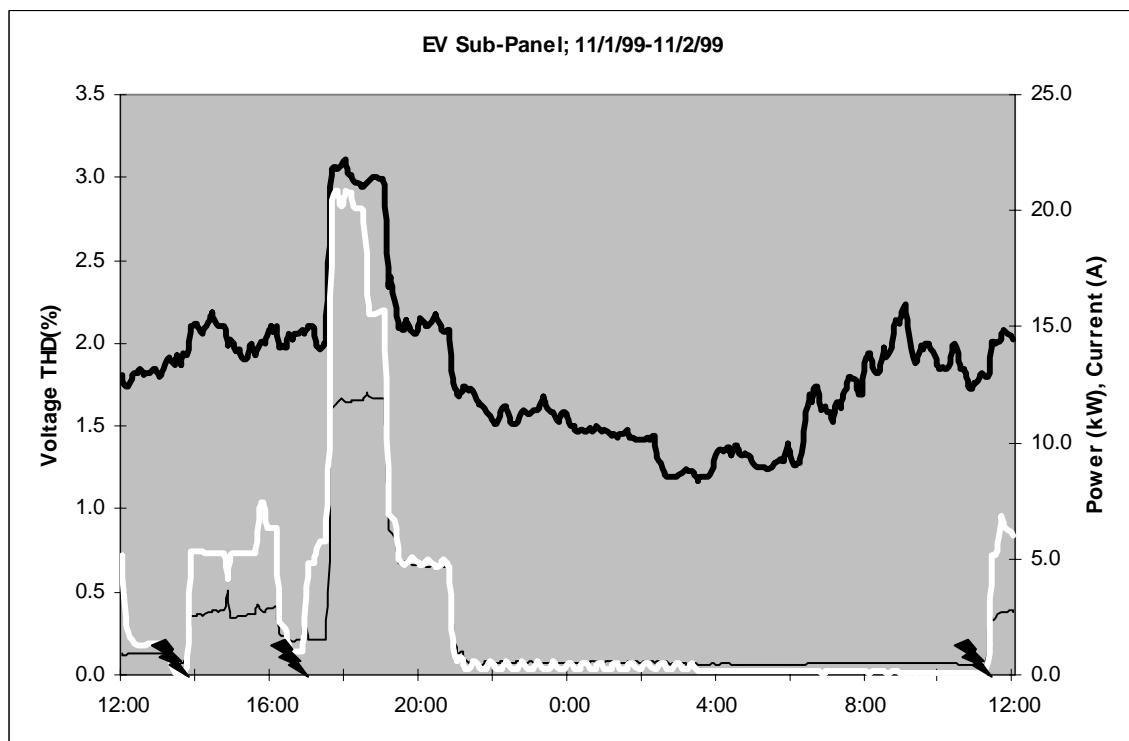
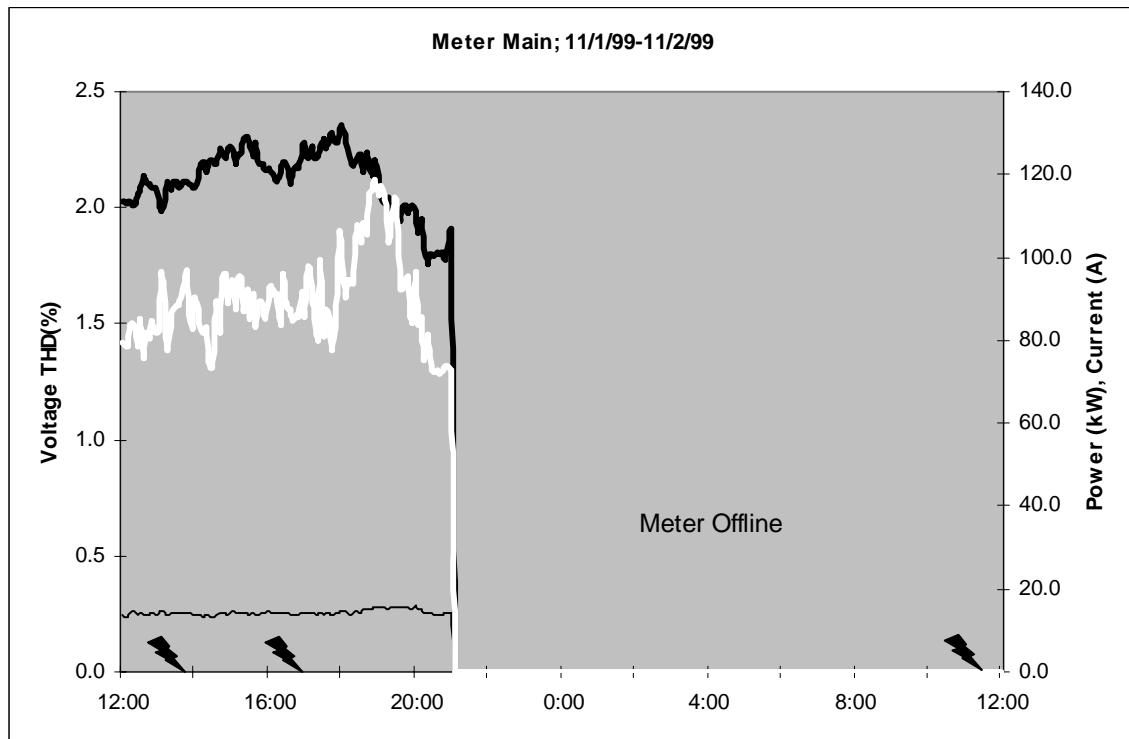


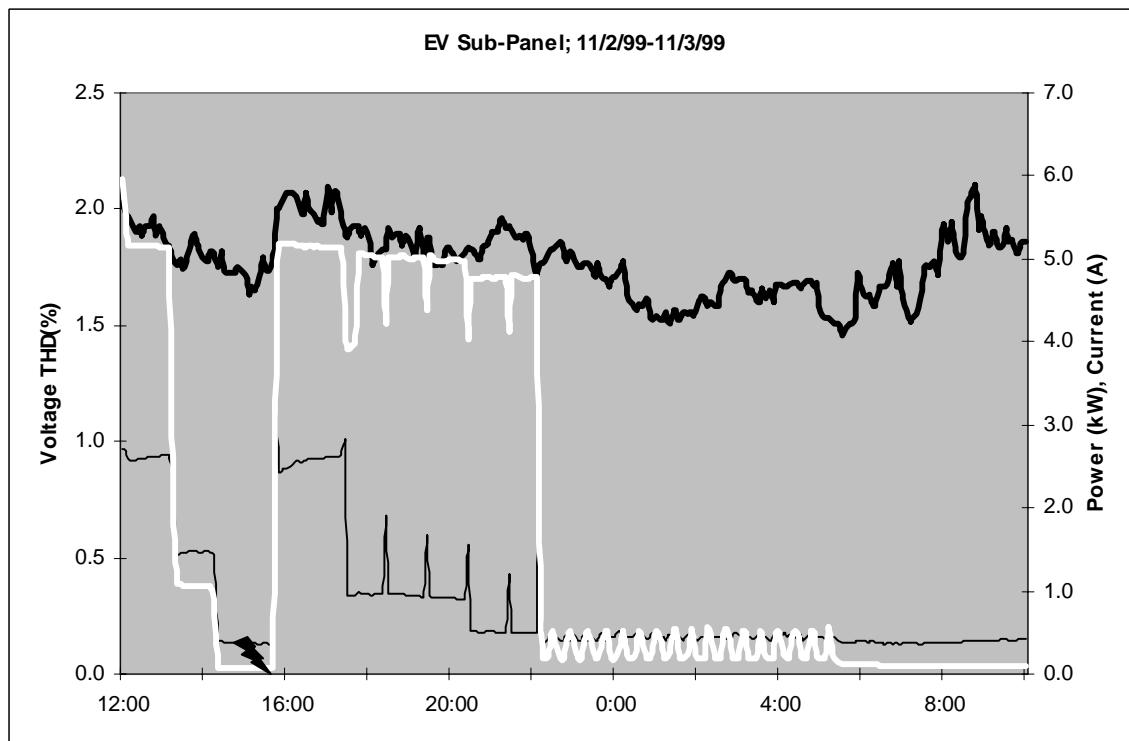
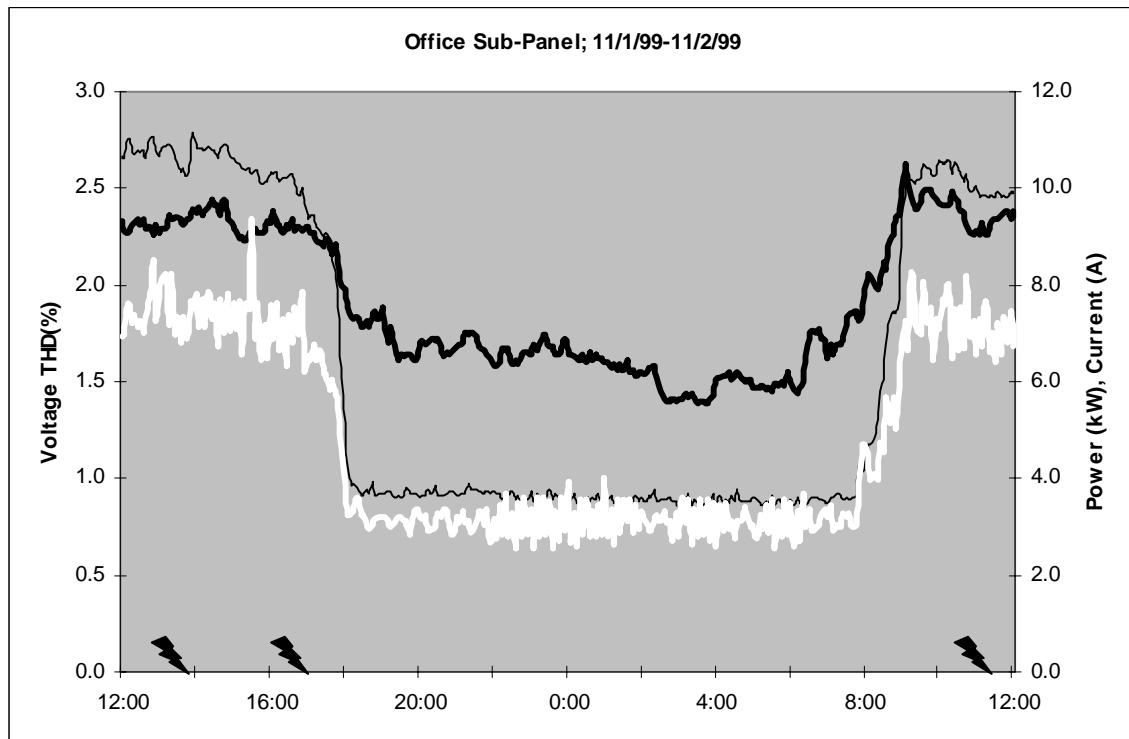


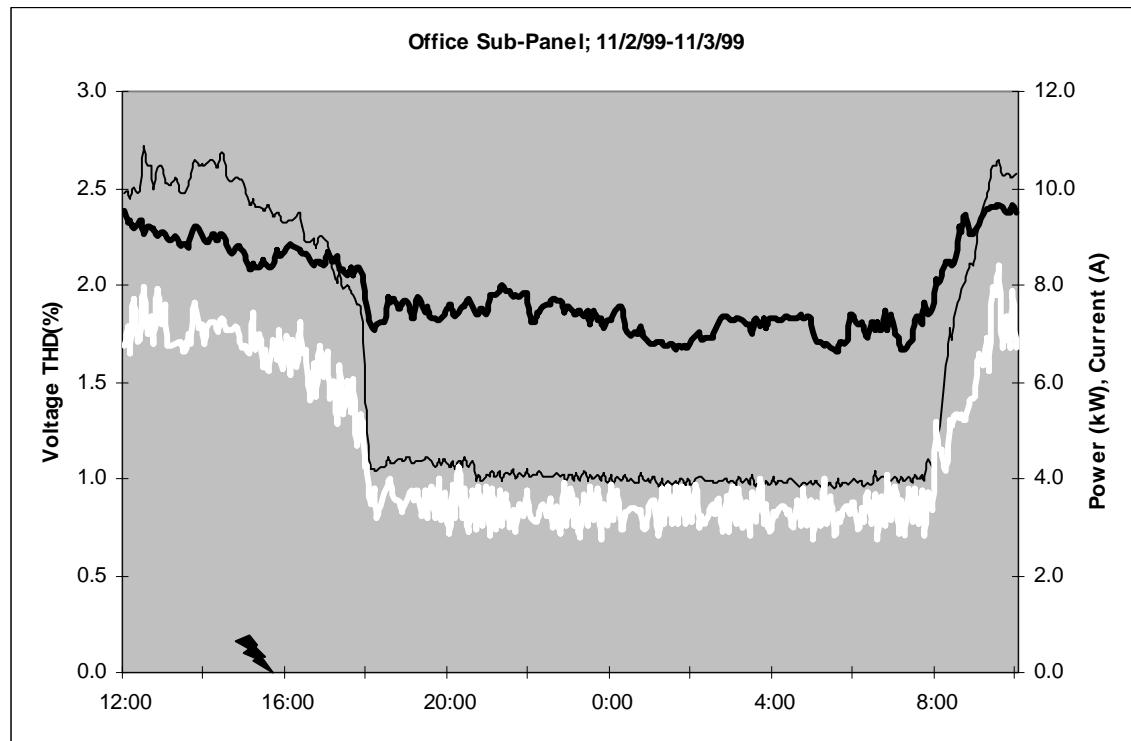




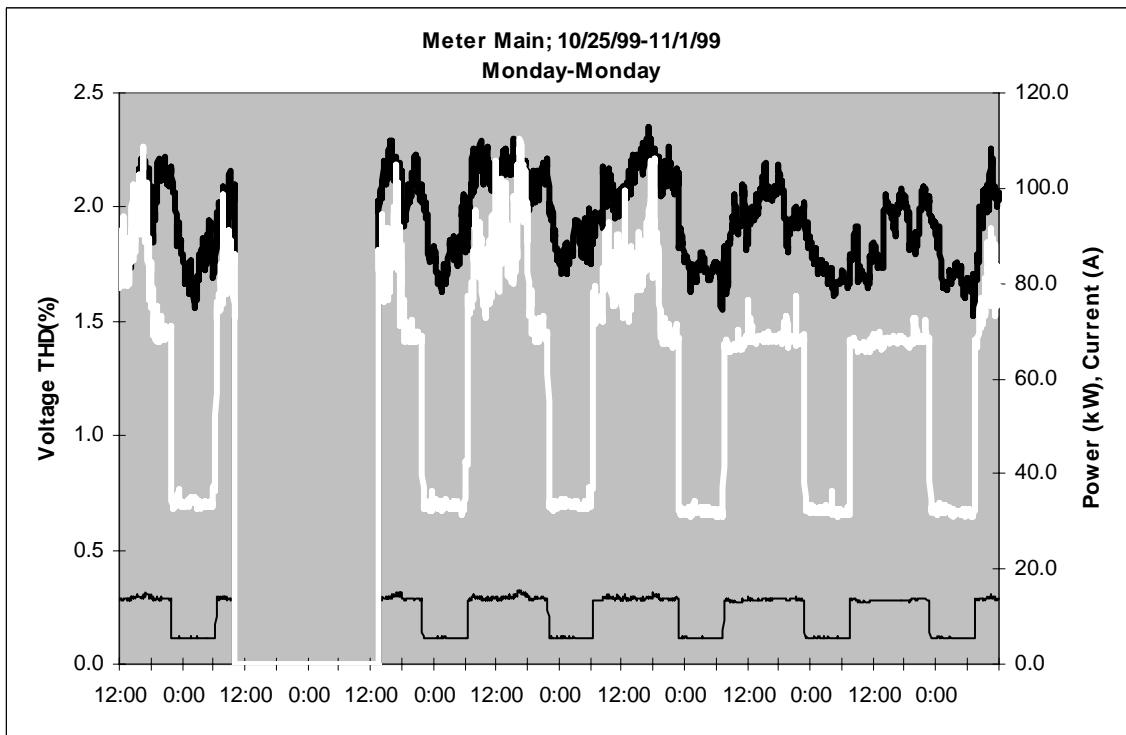
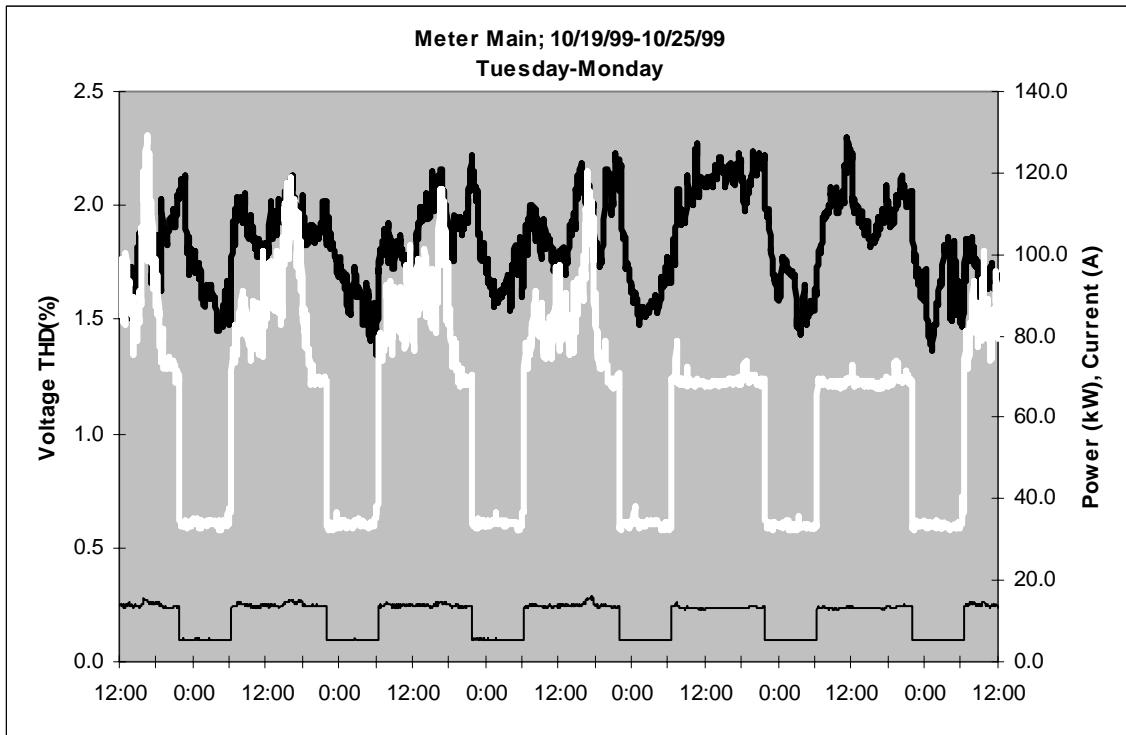








UTILITY C WEEKLY GRAPHS





Appendix D.4

Utility B Field Site Simulation Summary



Secondary Distribution Effects of EV Chargers Utility B

Field Site Simulation

The results of the simulations for the field site are presented below. A particular day on which three chargers turned on at midnight was chosen and the loading for the various consumers was constructed from field site data for that day.

Field Case Scenario

The Honda EVPLUS and Nissan Altra EVs were used in the field site. The EV charger models were EVI ICS-200 for the EVPLUSs and Magnecharge for the Altras. The current waveforms and their harmonic spectrum are shown in Figs. 1 and 2. The field site configuration is shown in Fig. 3. The source voltage was assumed to have a background voltage distortion of 3.4%, which was the typical voltage THD for the system obtained from the field data. The simulation parameters are shown in Tables A and B. The results obtained are shown in Fig. 3 and Table C. The system performance with regard to line and transformer losses is shown in Table D.

It was seen in the field site results that there was an extraneous load of 5 kW, which was switched on at the same time when the chargers came on. This load did not occur in any of the four houses with the EVs as can be seen from the RPM data. To account for this in the simulation, the extra loads coming on at midnight have been assumed as a dishwasher (in house #3) and other home-office loads (in houses #1 and #3). In all tables and figures, the two phases of the split phase secondary of the distribution transformer have been referred to as lines X1 and X3.

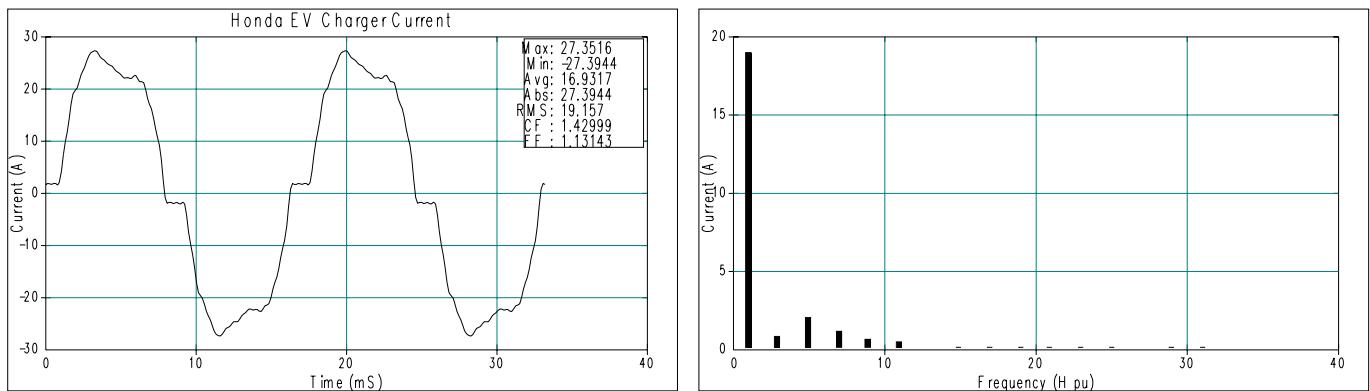


Fig 1. Honda EV Charger Current Waveform and Spectrum

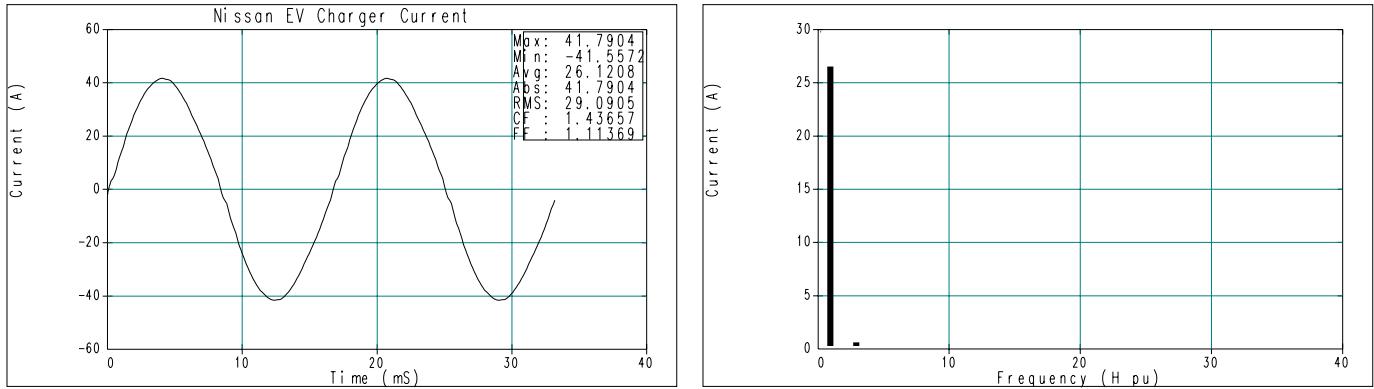
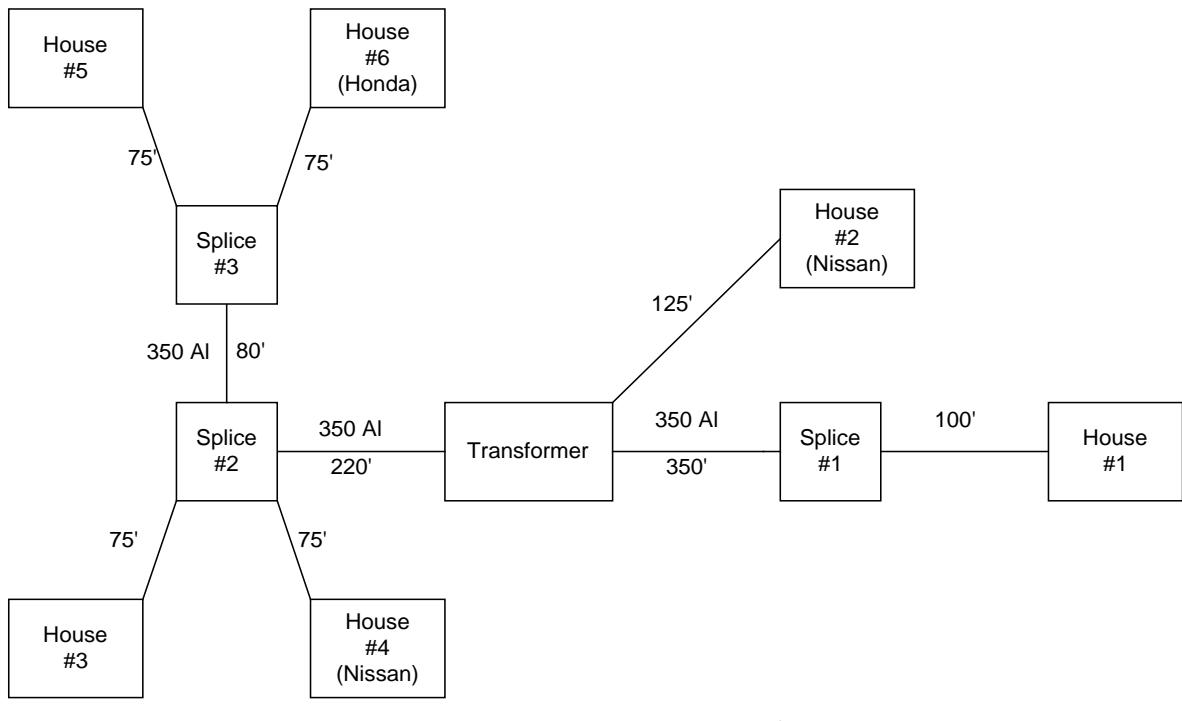


Fig 2. Nissan EV Charger Current Waveform and Spectrum

Table A. Simulation Parameters

Parameter	Value
EV Charger Penetration %	50
Distribution Service Transformer	50 kVA %Z=2.2 %R=1.5, %X=1.7
Secondary Conductor Used	350 Al
Service Conductor Used	4/0 Al
No. of customers	6
Total Load before Charging	6.0 kW
Total Load during Charging	29.8 kW
% Loading during Charging	59.6 %



Note: All service drops are 4/0 AI

Fig. 3. Field Site Configuration for Worst Case Simulation

Table B. Appliances used in simulation

Appliance	Load (kW)	Appliance	Load (kW)
House #1		House #2	
Refrigerator	0.7	Refrigerator	1.0
Lights	0.3	Lights	0.4
Computer	0.6	Nissan EV Charger	7.1
Total Load	1.6	Total Load	8.5
House #3		House #4	
Computer	0.4	Refrigerator	0.8
Printer	1.0	Fan	0.3
Dishwasher	2.5	Nissan EV Charger	7.1
Total Load	3.9	Total Load	8.2
House #5		House #6	
Refrigerator	0.5	Lights	0.6
Office Jet/FAX	1.4	Honda EV Charger	5.1
Total load	1.9	Total Load	5.7

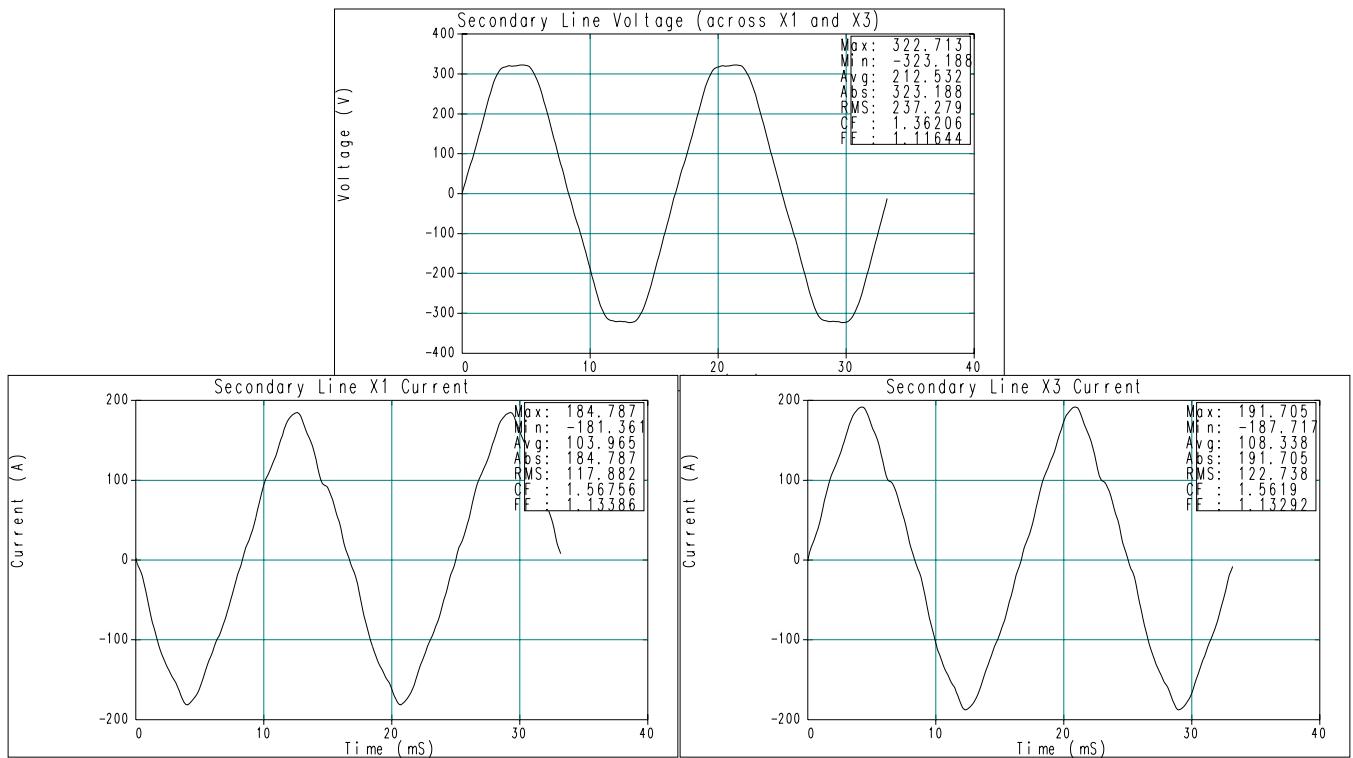


Fig 3. Field Site simulation results

Table C. Field Site Simulation Results

	X1 Line Curr.			X3 Line Curr.			Sec. Line Volt.(V)	Sec. Line Voltage THD (%)
	Sim (A)	THD (%)	Distortion Current (A)	Sim. (A)	THD (%)	Distortion Current (A)		
Before Charging	26.2	21.1	5.3	30.8	17.8	5.4	239.5	3.5
During Charging	117.9	7.6	8.8	122.7	7.3	9.0	237.3	3.6

Table D. Line and Transformer Losses

	Line Losses (W)	Transformer Winding Losses (W)	K Factor	Transformer Derating
Before Charging	8.3	16.6	1.5	0.98
During Charging	140.4	252.1	1.1	1.0

Comparative Study

A comparison of the field simulation results and the actual field data was performed. The comparison of the results is shown in Table E. The field data and the simulation results for the voltage THD match within 2.9%, thus validating the simulation process.

Table E. Comparison of simulation results and field data

	Before Charging			During Charging		
	Simulation	Field Data	% Diff.	Simulation	Field Data	% Diff.
X1 Line Current	26.2 A 21.1% THD	24.4 A 23.4% THD	7.4 -9.8	117.9 A 7.6% THD	123.8A 7.2% THD	-4.8 5.6
X3 Line Current	30.8 A 30.8% THD	31.3 A 24.1% THD	-1.6 27.8	122.7 A 7.3% THD	127.3 A 7.1 % THD	-3.6 2.8
Secondary Voltage	119.8 V 3.5% THD	123.8 V 3.4% THD	-3.2 2.9	118.9 V 3.6% THD	123.1 V 3.5% THD	-3.4 2.9
Line Losses	8.3 W	10.1 W	-17.8	16.6 W	18.2 W	-8.8
Transformer Losses	140.4 W	146.2 W	-4.0	252.1 W	288.2 W	-12.5
K Factor	1.5	1.6	-6.3	1.1	1.1	0.0
Transformer De-rating	0.98	0.98	0.0	1.0	1.0	0.0

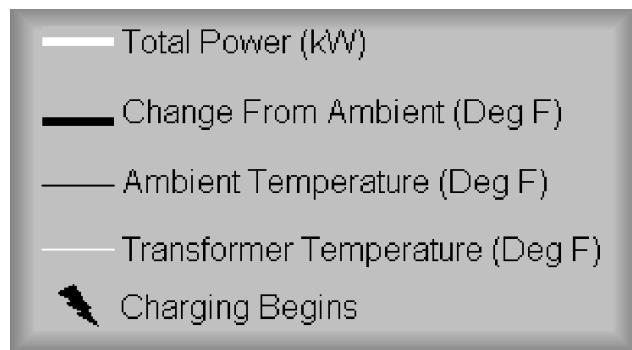


Appendix D.5

Utility B Temperature Data



Temperature Daily Graphs



Legend for Temperature Related Graphs

(Graph Scales are different for clarity)

